NASA TM- 81889

NASA Technical Memorandum 81889

NASA-TM-81889 19800024885

LOADS CALIBRATIONS OF STRAIN GAGE BRIDGES ON THE DAST PROJECT AEROELASTIC RESEARCH WING (ARW-1)

CLINTON V. ECKSTROM

OCTOBER 1980

NASA
National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

LOADS CALIBRATIONS OF STRAIN GAGE BRIDGES ON THE DAST PROJECT AEROELASTIC RESEARCH WING (ARW-1)

by

Clinton V. Eckstrom

ABSTRACT

This paper presents details of and results from the procedure used to calibrate strain gage bridges for measurement of wing structural loads, i.e., shear (V), bending moment (M), and torque (T), for the DAST project ARW-1 wing which has an aspect ratio of 6.8, a quarter-chord line sweepback angle of 42.24^{o}, and a taper ratio of 0.36. Results are in the form of loads equations and comparison of computed loads vs. actual loads for two simulated flight loading conditions.

INTRODUCTION

The first Aeroelastic Research Wing (ARW-1) undergoing flight testing as part of the Drones for Aerodynamic and Structural Testing (DAST) program is a supercritical wing of shape and planform similar to that of the F-8 supercritical wing airplane (reference 1) but of smaller size as appropriate for the BQM-34F drone aircraft. The primary purpose of this wing (ARW-1) is to evaluate an active control-flutter suppression system. The secondary purpose of the ARW-1 is to evaluate the effects of wing flexibility on aerodynamic loads measurements obtained over a range of Mach number and dynamic pressure flight test conditions. The aerodynamic loads measurements are being obtained in two forms, i.e., directly through chordwise surface pressure measurements and indirectly or in integrated form through determination of the structural loads, shear (V), bending moment (M), and torque (T). The surface pressure measurements are obtained at four spanwise stations on the right wing semi-span. The structural loads, which are derived from strain gage bridge measurements, are obtained at two spanwise stations on the right wing semi-span and at one station on the left wing semi-span.

N80-33393 #

The purpose of this paper is to document the procedures used to obtain the equations which define the relationship between structural loadings, V, M and T, and the strain gage bridge outputs and to provide an evaluation of the accuracy of the equations by comparison of computed vs. actual loads for two simulated flight loading conditions.

SYMBOLS

L_i	ith general load (V, M, or T)
M	bending moment, N-m (in.-lbs)
T	torque, N-m (in.-lbs)
V	shear, N (lbs)
β_{ij}	coefficient of jth bridge for ith load equation, load/mV
μ_j	output of jth bridge, mV
X_W, Y_W	axis system oriented perpendicular and parallel to wing 25 percent chord line with origin at vehicle centerline
X_{W_1}, Y_{W_1}	left wing axis system perpendicular and parallel to the wing 25 percent chord line with origin at Y_W = 1.118 m (44.0 in.)
X_{W_2}, Y_{W_2}	right wing axis system perpendicular and parallel to the wing 25 percent chord line with origin at Y_W = 1.118 m (44.0 in.)
X_{W_3}, Y_{W_3}	right wing axis system perpendicular and parallel to the wing 25 percent chord line with origin at Y_W = 1.880 m (74.0 in.)

WING AND INSTRUMENTATION

Wing

The ARW-1 is an early type supercritical wing designed for cruise at a high transonic speed (Mach number of 0.98). The airfoil shapes are defined in reference 2, and the wing characteristics are listed in table I. The general arrangement of the BQM-34F drone aircraft with the ARW-1 wing is shown in figure 1 and a photograph of the aircraft and wing during assembly check out is shown in figure 2.

The wing structure consists of a wing center section and right and left wing panels with removable leading and trailing edges and tip section as shown in figure 3. The wing center section was machined from a thick aluminum plate in a configuration to provide a high degree of stiffness without consideration of minimum weight. The center section is located on the fuselage at the same position as the standard target drone wing and uses the same attachment bolt locations. The outboard ends of the center section are in a plane normal to the 25-percent chord line of the outer wing panels.

The primary structure of the wing panels, as shown in the photograph of figure 4, consists of a spar at the 25-percent chord line, a spar at the 60-percent chord line, upper and lower stringers at the 42.5-percent chord line, and ribs located perpendicular to the front spar (on a 12-inch spacing). A special tip rib functions as an outboard spar end fitting. The upper and lower fiberglass skins between spars are riveted in place whereas the fiberglass skins for the leading and trailing edge sections, and the tip section are held in place with removable screw fasteners. The wing panels fasten to the center section with two tension bolts at each spar.

The front and rear spars are fabricated of 17-4 PH stainless steel material whereas the stringers, ribs and outboard spar end fitting are fabricated of 7075-T6 aluminum alloy. Fiberglass was selected as the skin material and oriented to give low torsional stiffness as desired for flutter considerations. This was achieved by aligning the fiberglass filaments parallel and perpendicular to the wing front spar so that the torsional stiffness is essentially the stiffness of the binder material (matrix).

Vehicle Assembly

To accomplish the loads calibration of the ARW-1 wing, it was assembled on a new, spare, BQM-34F fuselage. The assembly included the wing gloves which were mounted to the fuselage. The entire assembly was inverted and placed on a special stand as shown in figure 5. The assembly was inverted for the loadings so that the inert masses (shot bags seen hanging from the wing in fig. 5) could conveniently apply forces in the proper direction.

Some negative loadings were also required and these were achieved by means of a cable-pulley arrangement.

Strain Gage Bridges

The wing was equipped with two identical sets of strain gage bridges, some oriented to be primarily responsive to shear loads and others to bending moment loads, at eight locations as shown in figure 6. A total of 32 strain gage bridges were installed. One set of 16 bridges consisting of one shear and bending moment strain gage bridge at each location is monitored during flight testing for loads measurement purposes. Individual gages in the second set of 16 shear and bending moment type strain gage bridges are available for backup use in case of failure of a primary bridge or for use as sensors for monitoring wing flutter. Two additional torsion-sensitive strain gage bridges were located inboard on each wing semi-span as sensors for monitoring wing flutter but they are not reported on herein.

The triangular arrangement of the bridges at the inboard station on each wing half gives special consideration to the use of axis systems oriented either parallel and perpendicular to the fuselage center line or parallel and perpendicular to the wing 25-percent chord line (along the front spar); the latter will be referred to as a swept axis system. The bridges at the midwing location on the right wing half are oriented for the swept axis system only. Initially the swept axis system was oriented parallel and perpendicular to the 42.5 percent chord line (midway between the front and rear spar) since it was considered that this would be closer to the wing elastic axis. However, the swept axis was shifted to the 25 percent chord line (along the front spar) when it was found that the torsion load data correlated much better with the strain gage bridge outputs when the 25 percent chord line axis was used as the reference. Although the bridge arrangement at the inboard stations allows use of axis systems parallel and perpendicular to the fuselage centerline , the construction of the wing and the aspect ratio and sweep of the ARW-1 wing make the swept axis system more appropriate for use in following analysis.

Tables II and III identify the various strain gage bridges by assigned number, the mounting structure, the spanwise location, and the bridge type.

Note that on the right wing bridge no's. 1 through 10 constitute a set and that bridges 11 through 20 are an identical set with identical bridges having a numbering difference of 10 (i.e., bridges numbered 1 and 11 are identical as are 2 and 12, etc.). On the left wing the same numbering system was used (i.e., bridges numbered 21 and 31 are identical).

All of the strain gage bridges were subjected to an input or excitation of 10 volts. It should be noted that none of the strain gage bridge circuits had provisions to zero the bridge output for the zero load condition. Therefore, it was necessary to subtract out the zero load bridge output from all of the strain gage bridge readings taken during the calibration loading process. Shunt resistors were later added to the bridge circuitry to shift or bias the zero load bridge output so that during flight testing the expected bridge output variation would not exceed the available range of the telemetry channels on the aircraft downlink data system.

The selection of which one of a pair of identical strain gage bridges was to be monitored for the initial flight loads measurements setup and which one should remain as the spare or backup was based on the ease with which the individual bridges could be biased and amplified to make the best use of the available range on the telemetry downlink channel. The selected use status for each bridge is also defined in tables II and III. Only those strain gage bridges that were to be monitored for flight loads measurement purposes are considered as being available for inclusion in the regression analysis procedure to be discussed later.

CALIBRATION PROCEDURE

The calibration procedure consisted of: (1) determining the electrical imbalance or output of the strain gage bridges for a large variety of wing loading conditions and (2) using a regression analysis as described in reference 3, to establish a relationship (in the form of loads equations) between the strain gage bridge outputs and the applied wing loads in terms of shear (V), bending moment (M), and torque (T). Additional wing loadings were then used to check the accuracy of the established loads equations. For the ARW-1, results from both point and multipoint loading conditions were combined and used as input data to establish the loads equations. Two

different sets of simulated flight loadings were applied and used to check the accuracy of the established loads equations.

Single Point Loading Conditions

Single point loads were applied individually at the locations shown in figure 7. Table IV lists the magnitudes of the applied loads and the x and y location of the point of application. The resulting differential electrical imbalance or output of each of the strain gage bridges for each of the single point loadings is listed in Table V along with the wing loading in terms of shear (V), bending moment (M), and torque (T) for the appropriate wing station. These data, along with similar data from the multipoint loadings, were used as the input to the regression analysis for determination of the loads equations.

The loads applied along the stringer located between the spars was by means of scale weights placed on a 4-in. by 4-in. square pad of aluminum with a lower surface of soft rubber so that the wing surface would not be damaged. Application of loads at all other locations was provided for by removing a screw holding the wing skin leading edge, trailing edge or tip section, and replacing it with an eye screw. With the wing in the inverted position the loads listed in Table IV were achieved by hanging either scale weights or lead shot bags from the eye screws inserted in the wing upper surface.

Multipoint Loading Conditions

The steps in applying loads for the multipoint loading process are listed in Table VI. Note that the loads were applied sequentially in 12 increments on each wing, with each additional load at a new location, and that the sequence was repeated three times for a total of 36 loading conditions on the up load. By following the same sequence during the down loading process an additional 33 distinct loading conditions were achieved along with three repeats of previous loading conditions. The electrical imbalance or output of each of the strain gage bridges as measured for each of the 72 steps in the process is listed in Table VII.

For the multipoint loading procedure all loads were again applied by hanging weights from eye screws on the wing upper surface. The photograph of figure 5 was taken during the multipoint loading procedure near the maximum loading condition. Equal loads were applied to or removed from both the right and left wing semi-spans at each step of the loading procedure to prevent large moments which could cause rotation of the fuselage in the support stand.

Simulated Flight Loading Conditions

The loadings and locations for the two simulated flight loadings are defined in tables VIII and IX and the electrical imbalance or output of each strain gage bridge is listed in table X. The first simulated flight loading represented the design loading condition analyzed for the straight and level flight at cruise condition. The second simulated flight loading represented the 2½-g loading analyzed as the maximum load for stress analysis. All loads on both wing semi-spans were in the positive direction and were applied by hanging weights from eye screws. For each loading condition the entire load was applied before the strain gage bridge outputs were recorded.

Loads Equations

Loads equations for calculating wing loadings as a function of the output of selected strain gage bridges were determined by means of the standard regression analysis methods described in reference 3. These load equations have the form:

$$L_i = \begin{bmatrix} \beta_{11} & \beta_{12} & \beta_{13} & \cdot & \cdot & \cdot & \beta_{1j} \\ \beta_{21} & \beta_{22} & \beta_{23} & \cdot & \cdot & \cdot & \beta_{2j} \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \beta_{i1} & \beta_{i2} & \beta_{i3} & & & & \beta_{ij} \end{bmatrix} \begin{Bmatrix} \mu_1 \\ \mu_2 \\ \cdot \\ \cdot \\ \mu_j \end{Bmatrix}$$

where β_{ij} is the coefficient of the jth bridge for ith load, and μ_j is the output of the jth bridge.

The regression analysis can be performed using one or as many of the strain gage bridges as are available at each wing station. A stepwise regression analysis procedure (reference 4) was used which selects the best single strain gage bridge, then goes on to select a second bridge that, when used with the first bridge selected, gives the best combination of two bridges and continues on in the same manner to include as many bridges as are available for the location and axis system being used. The structural loads equations presented herein are for the swept axis system only. For example, for the right wing inboard station swept axis system, only strain gage bridges 13, 4, 15, and 6 were used in the regression analysis. Similarily for the left wing inboard station only strain gage bridges 23, 34, 35, and 36 were in the regression analysis.

Data from both the single-point and the multipoint loadings (tables V and VII) were combined and used as input for the regression analysis. Table XI indicates which bridges were selected for each load measurement, shear (V), bending moment (M), and torque (T), and presents the associated load coefficients (β_{ij}) and probable errors along with the standard error of estimate for the equation and the multiple correlation coefficient which is an indication of how well the calibration data fit the linear regression equation selected. In all cases, except one, the multiple correlation coefficient is better than 0.9990. (A value of zero being no fit and a value of 1.0 being a perfect fit.) The one exception is for the torque equation for the right wing midwing station where the multiple correlation coefficient is 0.99754. Figures 8 through 16 provide a visual idea of how well the selected loads equations correlate with the data from which they are derived. These figures present load as calculated using the selected loads equations as a function of applied load for both single point and multi-point loadings. For a perfect correlation all the data would fall on a straight line with a one to one relationship between applied load and computed load.

The selected load equations were also used to estimate the loads applied during the two simulated flight loadings, table X. Results are presented in

table XII. For all shear and bending moment loads the selected load equations predicted the loads within ±4 percent of the actual applied load. For the torsion moment loads the selected loads equations were less accurate. For the load simulating the straight and level design point flight condition, the equations underpredicted the torsion load by 4 to 8 percent. For the load simulating a 2.5 g maneuver flight condition, the equations overpredicted the torsion load 3 to 5 percent at the inboard stations and by 26 percent at the right wing midwing station. The results are considered satisfactory except for the torque load estimate for the right wing midwing station.

CONCLUDING REMARKS

The ARW-1 Aeroelastic Research Wing consists of conventional spar, stringer, rib and skin construction. Strain gage bridges sensitive to shear and bending moment loads were installed for load measurement purposes at two spanwise locations on the right wing half and at one location on the left wing half. Results from both the single point and multipoint loadings were combined for use as input to the stepwise regression analysis used to derive loads equations for each load type (V, M, and T) at each wing station. Comparison of loads predicted using the derived loads equations with actual applied loads for the two simulated flight loading conditions indicated excellent results for shear and bending moment loads (within ±4 percent). At the right and left inboard wing stations, the predicted torsion loads are good (within ±6 percent). The predicted torsion loads at the right wing midwing station were less accurate than desired (error ranging from 8 to 26 percent).

REFERENCES

1. Anon.: Supercritical Wing Technology — A Progress Report on Flight Evaluations. NASA SP-301, 1972.
2. Byrdsong, Thomas A.; and Hallissy, James B.: Longitudinal and Lateral Static Stability and Control Characteristics of a 1/6-Scale Model of a Remotely Piloted Research Vehicle With a Supercritical Wing. NASA TP-1360, 1979.
3. Skopinski, T. H.; Aiken, William S., Jr.; and Huston, Wilber B.: Calibration of Strain-Gage Installations in Aircraft Structures for the Measurement of Flight Loads. NACA Rep. 1178, 1954. (Supersedes NACA TN 2993)
4. Furnival, G. M.; and Wilson, R. W.: Regressions by Leaps and Bounds. Technometrics, vol. 16, no. 4, November 1974.

TABLE I.- WING CHARACTERISTICS

Aspect ratio	6.8	
Taper ratio	0.36	
Sweepback angle at ¼ chord line, deg.	42.24	
Reference area, m^2 ($ft.^2$)	2.78	(30.0)
Thickness at root, percent chord	11.0	
Thickness at tip, percent chord	7.0	
Span, m (in.)	4.343	(171.0)
Tip chord length, m (in.)	0.343	(13.51)
Root chord length, m (in.)	0.940	(36.99)
Mean aerodynamic chord (MAC) length, m (in.)	0.687	(27.06)

TABLE II.- IDENTIFICATION OF STRAIN-GAGE BRIDGES -RIGHT WING

Bridge No.	Structure	Y_W m	(in.)	Bridge Type	Use
1	F.S.	0.927	(36.5)	V	Backup
2	F.S.	0.927	(36.5)	M	Loads
3	F.S.	1.118	(44.0)	V	Backup
4	F.S.	1.118	(44.0)	M	Loads
5	R.S	1.118	(44.0)	V	Backup
6	R.S.	1.118	(44.0)	M	Loads
7	F.S.	1.880	(74.0)	V	Loads
8	F.S.	1.880	(74.0)	M	Backup
9	R.S.	1.880	(74.0)	V	Loads
10	R.S.	1.880	(74.0)	M	Loads
11	F.S.	0.927	(36.5)	V	Loads
12	F.S.	0.927	(36.5)	M	Backup
13	F.S.	1.118	(44.0)	V	Loads
14	F.S.	1.118	(44.0)	M	Backup
15	R.S.	1.118	(44.0)	V	Loads
16	R.S.	1.118	(44.0)	M	Backup
17	F.S.	1.880	(74.0)	V	Flutter
18	F.S.	1.880	(74.0)	M	Loads
19	R.S.	1.880	(74.0)	V	Backup
20	R.S.	1.880	(74.0)	M	Backup

F.S. = front spar, R.S. = rear spar, V = shear, M = bending moment.

TABLE III.- IDENTIFICATION OF STRAIN-GAGE BRIDGES - LEFT WING

Bridge No.	Structure	Y_W m	Y_W (in.)	Bridge Type	Use
21	F.S.	0.927	(36.5)	V	Backup
22	F.S.	0.927	(36.5)	M	Backup
23	F.S.	1.118	(44.0)	V	Loads
24	F.S.	1.118	(44.0)	M	Backup
25	R.S.	1.118	(44.0)	V	Backup
26	R.S.	1.118	(44.0)	M	Backup
31	F.S.	0.927	(36.5)	V	Loads
32	F.S.	0.927	(36.5)	M	Loads
33	F.S.	1.118	(44.0)	V	Flutter
34	F.S.	1.118	(44.0)	M	Loads
35	R.S.	1.118	(44.0)	V	Loads
36	R.S.	1.118	(44.0)	M	Loads

F.S. = front spar, R.S. = rear spar, V = shear, M = bending moment.

TABLE IV. - SINGLE POINT APPLIED LOADS AND LOCATIONS

Part A. - Left Wing, Inboard Station

Location No. (See Fig. 7)	Applied Load N	(lbs)	Location Coordinates Y_{W1} m	(in.)	X_{W1} m	(in.)
1	890	(200)	0.058	(2.30)	-0.012	(-0.47)
2	890	(200)	0.066	(2.60)	0.095	(3.75)
3	890	(200)	0.058	(2.29)	0.203	(8.00)
4	712	(160)	0.363	(14.30)	-0.012	(-0.47)
5	712	(160)	0.371	(14.60)	0.087	(3.44)
6	712	(160)	0.362	(14.26)	0.185	(7.30)
7	712	(160)	0.670	(26.36)	-0.012	(-0.49)
8	712	(160)	0.675	(26.56)	0.079	(3.10)
9	712	(160)	0.667	(26.26)	0.168	(6.60)
10	667	(150)	0.975	(38.37)	-0.013	(-0.50)
11	445	(100)	0.979	(38.56)	0.071	(2.80)
12	667	(150)	0.972	(38.28)	0.151	(5.96)
13	534	(120)	1.279	(50.34)	-0.012	(-0.47)
14	222	(50)	1.285	(50.58)	0.061	(2.42)
15	534	(120)	1.278	(50.32)	0.134	(5.28)
16	356	(80)	1.578	(62.13)	-0.011	(-0.45)
17	222	(50)	1.667	(65.63)	0.048	(1.90)
18	356	(80)	1.723	(67.83)	0.110	(4.35)

TABLE IV. - Continued

Part B. - Right Wing, Inboard Station

Location No. (See Fig. 7)	Applied Load N	(lbs)	Location Coordinates Y_{W_2} m	(in.)	X_{W_2} m	(in.)
1	222	(50)	0.063	(2.48)	-0.089	(-3.52)
2	890	(200)	0.054	(2.14)	-0.013	(-0.51)
3	890	(200)	0.066	(2.60)	0.095	(3.75)
4	890	(200)	0.056	(2.21)	0.202	(7.95)
5	267	(60)	0.066	(2.60)	0.330	(12.98)
6	890	(200)	0.217	(8.13)	-0.013	(-0.50)
7	890	(200)	0.208	(8.19)	0.194	(7.62)
8	222	(50)	0.369	(14.51)	-0.083	(-3.25)
9	712	(160)	0.362	(14.26)	-0.012	(-0.48)
10	667	(150)	0.371	(14.60)	0.087	(3.44)
11	712	(160)	0.362	(14.26)	0.185	(7.30)
12	267	(60)	0.368	(14.50)	0.273	(10.75)
13	667	(150)	0.511	(20.12)	-0.013	(-0.50)
14	667	(150)	0.515	(20.26)	0.177	(6.98)
15	133	(130)	0.674	(26.55)	-0.074	(-2.90)
16	667	(150)	0.665	(26.20)	-0.012	(-0.49)
17	667	(150)	0.675	(26.56)	0.079	(3.10)
18	667	(150)	0.669	(26.32)	0.168	(6.60)

TABLE IV. - Continued

Part B. - Concluded

Location No. (See Fig. 7)	Applied Load N	(lbs)	Location Coordinates Y_{W_2} m	(in.)	X_{W_2} m	(in.)
19	133	(30)	0.673	(26.50)	0.241	(9.48)
20	667	(150)	0.818	(32.21)	-0.013	(-0.50)
21	667	(150)	0.820	(32.27)	0.160	(6.30)
22	200	(45)	0.979	(38.56)	-0.053	(-2.10)
23	667	(150)	0.971	(38.22)	-0.013	(-0.50)
24	400	(90)	0.979	(38.56)	0.071	(2.80)
25	667	(150)	0.971	(38.24)	0.151	(5.96)
26	200	(45)	0.980	(38.60)	0.206	(8.10)
27	534	(120)	1.124	(44.25)	-0.012	(-0.49)
28	534	(120)	1.127	(44.36)	0.143	(5.63)
29	200	(45)	1.287	(50.68)	-0.048	(-1.88)
30	534	(120)	1.275	(50.19)	-0.012	(-0.49)
31	267	(60)	1.285	(50.58)	0.061	(2.42)
32	534	(120)	1.280	(50.38)	0.134	(5.28)
34	400	(90)	1.444	(56.86)	-0.011	(-0.45)
35	400	(90)	1.441	(56.75)	0.127	(5.00)
36	200	(45)	1.547	(60.91)	-0.041	(-1.63)
37	400	(90)	1.574	(61.96)	-0.011	(-0.45)
38	267	(60)	1.666	(65.58)	0.050	(1.95)
39	400	(90)	1.720	(67.70)	0.112	(4.40)
40	200	(45)	1.745	(68.72)	0.141	(5.55)

TABLE IV. - Concluded

Part C. - Right Wing, Midwing Station

Location No. (See Fig. 7)	Applied Load N	(lbs)	Location Coordinates Y_{W_3} m	(in.)	X_{W_3} m	(in.)
20	667	(150)	0.056	(2.21)	-0.013	(-0.50)
21	667	(150)	0.058	(2.27)	0.160	(6.30)
22	200	(45)	0.217	(8.56)	-0.053	(-2.10)
23	667	(150)	0.209	(8.22)	-0.013	(-0.50)
24	400	(90)	0.217	(8.56)	0.071	(2.80)
25	667	(150)	0.209	(8.24)	0.151	(5.96)
26	200	(45)	0.218	(8.60)	0.206	(8.10)
27	534	(120)	0.362	(14.25)	-0.012	(-0.49)
28	534	(120)	0.365	(14.36)	0.143	(5.63)
29	200	(45)	0.525	(20.68)	-0.048	(-1.88)
30	534	(120)	0.513	(20.19)	-0.012	(-0.49)
31	267	(60)	0.523	(20.58)	-0.061	(2.42)
32	534	(120)	0.518	(20.38)	0.134	(5.28)
34	400	(90)	0.682	(26.86)	-0.011	(-0.45)
35	400	(90)	0.679	(26.75)	0.127	(5.00)
36	200	(45)	0.785	(30.91)	-0.041	(-1.63)
37	400	(90)	0.812	(31.96)	-0.011	(-0.45)
38	267	(60)	0.904	(35.58)	0.050	(1.95)
39	400	(90)	0.958	(37.70)	0.112	(4.40)
40	200	(45)	0.983	(38.72)	0.141	(5.55)

TABLE V.- WING LOADINGS AND STRAIN-GAGE BRIDGE OUTPUTS FOR SINGLE-POINT APPLIED LOADS

(A) LEFT WING, INBOARD STATION

WING LOADINGS			STRAIN-GAGE BRIDGE OUTPUTS, MILLIVOLTS											
SHEAR, LBS	MOMENT, IN-LBS	TORQUE, IN-LBS	MU 21	MU 22	MU 23	MU 24	MU 25	MU 26	MU 31	MU 32	MU 33	MU 34	MU 35	MU 36
200.00	460.00	-94.00	.651	.810	.778	-.038	.126	.373	.655	.843	.796	-.051	.120	.369
200.00	520.00	750.00	.392	.699	.440	.244	.492	.285	.392	.719	.425	.305	.474	.388
200.00	458.00	1600.00	.108	.581	.145	.330	.936	-.019	.110	.591	.138	.315	.922	.007
160.00	2288.00	-75.20	.423	1.452	.510	1.013	.138	.816	.429	1.485	.498	1.072	.133	.848
160.00	2336.00	550.40	.253	1.272	.308	.929	.407	.951	.255	1.306	.295	.961	.396	1.002
160.00	2281.60	1168.00	.126	1.087	.159	.837	.613	1.026	.130	1.114	.151	.866	.594	1.113
160.00	4217.60	-78.40	.377	2.227	.422	1.861	.117	1.507	.387	2.280	.415	1.945	.188	1.581
160.00	4249.60	496.00	.249	2.036	.272	1.752	.327	1.687	.257	2.081	.267	1.833	.324	1.784
160.00	4201.60	1056.00	.127	1.824	.137	1.612	.527	1.810	.133	1.870	.132	1.685	.513	1.934
150.00	5755.50	-75.00	.314	2.718	.319	2.446	.092	2.070	.326	2.790	.316	2.553	.094	2.175
100.00	3356.00	280.00	.137	1.720	.131	1.594	.176	1.500	.140	1.759	.131	1.667	.175	1.585
150.00	5742.00	894.00	.110	2.388	.089	2.238	.420	2.334	.119	2.442	.069	2.343	.411	2.472
120.00	6040.80	-56.40	.223	2.688	.202	2.524	.054	2.190	.234	2.749	.204	2.635	.060	2.303
50.00	2529.00	121.00	.060	1.086	.047	1.047	.074	.976	.064	1.111	.047	1.095	.076	1.031
120.00	6038.40	633.60	.078	2.467	.038	2.387	.281	2.375	.088	2.531	.041	2.500	.281	2.512
80.00	4970.40	-36.00	.126	2.126	.097	2.057	.021	1.808	.138	2.177	.101	2.147	.026	1.900
50.00	3281.50	95.00	.051	1.378	.027	1.366	.050	1.066	.056	1.408	.030	1.426	.055	1.322
80.00	5426.40	348.00	.038	2.160	.012	2.161	.144	2.080	.046	2.209	.005	2.226	.146	2.190

TABLE V.- CONTINUED

(B) RIGHT WING, INBOARD STATION

WING LOADINGS			STRAIN-GAGE BRIDGE OUTPUTS, MILLIVOLTS											
SHEAR, LBS	MOMENT, IN-LBS	TORQUE, IN-LBS	MU 1	MU 2	MU 3	MU 4	MU 5	MU 6	MU 11	MU 12	MU 13	MU 14	MU 15	MU 16
50.00	124.00	-176.00	.176	.227	.208	.016	.011	.101	.182	.229	.194	.011	-.006	.078
200.00	428.00	-102.00	.673	.812	.791	-.048	.119	.378	.674	.824	.777	-.078	.116	.338
200.00	520.00	750.00	.388	.665	.385	.254	.550	.289	.363	.673	.364	.301	.521	.376
200.00	442.00	1590.00	.096	.588	.124	.333	.992	.002	.094	.588	.110	.309	.991	.020
60.00	156.00	778.80	-.050	.138	-.049	.094	.405	.049	-.051	.139	-.048	.065	.392	.066
200.00	1626.00	-100.00	.615	1.349	.724	.662	.147	.667	.617	1.368	.692	.691	.142	.632
200.00	1638.00	1524.00	.136	.927	.156	.638	.878	.778	.133	.942	.142	.637	.847	.823
50.00	725.50	-162.50	.172	.482	.191	.322	-.009	.241	.175	.495	.182	.333	-.006	.229
160.00	2281.60	-76.80	.454	1.467	.501	1.012	.134	.838	.460	1.489	.482	1.042	.132	.804
150.00	2190.00	516.00	.253	1.192	.278	.866	.379	.938	.254	1.202	.264	.878	.368	.929
160.00	2281.60	1168.00	.126	1.078	.133	.824	.631	1.128	.127	1.091	.122	.826	.608	1.154
60.00	870.00	645.00	-.006	.364	-.008	.300	.312	.443	-.007	.374	-.012	.307	.303	.447
150.00	3018.00	-75.00	.405	1.712	.422	1.330	.118	1.118	.409	1.731	.410	1.361	.118	1.055
150.00	3039.00	1047.00	.129	1.340	.121	1.105	.538	1.453	.130	1.356	.111	1.130	.522	1.469
30.00	796.50	-87.00	.090	.420	.090	.356	.003	.268	.092	.421	.089	.371	.001	.261
150.00	3930.00	-73.50	.389	2.068	.362	1.710	.112	1.438	.394	2.086	.371	1.742	.113	1.410
150.00	3984.00	465.00	.243	1.860	.223	1.531	.325	1.665	.243	1.879	.213	1.622	.318	1.659
150.00	3948.00	990.00	.134	1.684	.108	1.467	.496	1.828	.135	1.706	.101	1.504	.485	1.836
30.00	795.00	284.40	.006	.311	.001	.274	.123	.377	.006	.317	-.002	.266	.120	.379
150.00	4831.50	-75.00	.368	2.348	.334	2.029	.102	1.771	.371	2.371	.327	2.070	.103	1.740
150.00	4840.50	945.00	.136	2.006	.091	1.800	.445	2.130	.137	2.030	.084	1.848	.436	2.129
45.00	1735.20	-94.50	.117	.801	.102	.733	.004	.615	.118	.809	.100	.747	.007	.605
150.00	5733.00	-75.00	.358	2.691	.301	2.386	.087	2.124	.364	2.717	.297	2.310	.090	2.091
90.00	3470.40	252.00	.139	1.525	.101	1.394	.164	1.417	.141	1.539	.100	1.425	.163	1.407
150.00	5736.00	894.00	.138	2.360	.071	2.170	.413	2.474	.139	2.384	.067	2.221	.405	2.469
45.00	1737.00	364.50	.011	.674	-.004	.638	.152	.769	.015	.654	-.005	.654	.150	.766
120.00	5310.00	-58.80	.269	2.379	.208	2.175	.061	1.977	.273	2.401	.206	2.218	.065	1.950
120.00	5323.20	675.60	.102	2.146	.035	2.028	.304	2.236	.104	2.164	.035	2.077	.301	2.226
45.00	2280.60	-84.60	.105	.983	.078	.934	-.002	.821	.108	.991	.079	.952	.001	.809
120.00	6022.80	-58.80	.261	2.657	.183	2.462	.049	2.267	.265	2.681	.185	2.509	.056	2.236
60.00	3034.80	145.20	.084	1.278	.043	1.223	.090	1.222	.086	1.288	.044	1.250	.090	2.212
120.00	6045.60	633.60	.106	2.424	.020	2.320	.276	2.503	.108	2.451	.020	2.374	.276	2.491
90.00	5117.40	-40.50	.184	2.181	.111	2.072	.027	1.923	.188	2.200	.114	2.111	.034	1.898
90.00	5107.00	450.00	.073	2.019	-.003	1.964	.189	2.081	.075	2.039	-.000	2.011	.190	2.067
45.00	2740.95	-73.35	.097	1.144	.058	1.110	.008	1.003	.099	1.152	.059	1.130	.002	.988
90.00	5576.40	-40.50	.179	2.352	.095	2.255	.019	2.108	.182	2.372	.099	2.296	.026	2.078
60.00	3934.80	117.00	.085	1.615	.023	1.563	.061	1.544	.088	1.628	.025	1.594	.066	1.528
90.00	6093.00	396.00	.073	2.453	-.027	2.364	.156	2.455	.050	1.618	-.014	1.610	.106	1.624
45.00	3092.40	249.75	.020	1.170	-.032	1.176	.091	1.238	.023	1.182	-.027	1.202	.093	1.230

TAPLE V.- CONCLUDED

(C) RIGHT WING, MIDWING STATION

WING LOADINGS			STRAIN-GAGE BRIDGE OUTPUTS, MILLIVOLTS							
SHEAR, LBS	MOMENT, IN-LBS	TORQUE, IN-LBS	MU 7	MU 8	MU 9	MU 10	MU 17	MU 18	MU 19	MU 20
150.00	331.50	-75.00	.924	-.039	.117	.479	.966	-.107	.107	.419
150.00	340.50	945.00	.126	.500	1.116	-.333	.116	.453	1.164	-.413
45.00	385.20	-94.50	.266	.264	.025	.293	.253	.257	.021	.274
150.00	1233.00	-75.00	.879	.679	.174	.910	.832	.868	.156	.859
90.00	770.40	252.00	.304	.590	.371	.517	.285	.582	.352	.486
150.00	1236.00	894.00	.183	.960	.921	.730	.166	.933	.887	.696
45.00	387.00	364.50	.013	.304	.312	.206	.009	.292	.303	.168
120.00	1710.00	-58.60	.591	1.327	.170	1.138	.554	1.323	.139	1.089
120.00	1723.20	675.60	.181	1.220	.621	1.198	.162	1.208	.591	1.143
45.00	930.60	-84.60	.215	.717	.034	.608	.201	.714	.027	.583
120.00	2422.80	-58.60	.513	1.886	.174	1.605	.479	1.880	.153	1.535
60.00	1234.80	145.20	.165	.923	.192	.866	.154	.920	.179	.826
120.00	2445.60	633.60	.185	1.726	.539	1.734	.162	1.534	.509	1.661
90.00	2417.40	-40.50	.330	1.844	.122	1.608	.305	1.841	.101	1.542
90.00	2407.50	450.00	.122	1.714	.359	1.686	.105	1.713	.333	1.616
45.00	1390.95	-73.35	.171	1.057	.031	.919	.159	1.064	.018	.881
90.00	2876.40	-40.50	.295	2.179	.107	1.930	.271	2.177	.085	1.085
60.00	2134.80	117.00	.131	1.551	.141	1.439	.115	1.550	.122	1.375
90.00	3393.00	396.00	.087	2.454	.291	1.938	.045	1.638	1.174	1.503
45.00	1742.40	249.75	.019	1.238	.166	1.203	.009	1.239	.150	1.149

TABLE VI. - MULTIPOINT APPLIED LOADS, LOCATIONS AND APPLICATION SEQUENCE.

LOADING STEP	APPLIED LOAD INCREMENTS (Each Wing) N	APPLIED LOAD INCREMENTS (Each Wing) (lbs)	APPLIED LOAD TOTAL (Each Wing) N	APPLIED LOAD TOTAL (Each Wing) (lbs)	LOCATION LEFT WING, INBOARD Y_{W_1} m	LEFT WING, INBOARD Y_{W_1} (in.)	LEFT WING, INBOARD X_{W_1} m	LEFT WING, INBOARD X_{W_1} (in.)	RIGHT WING, INBOARD Y_{W_2} m	RIGHT WING, INBOARD Y_{W_2} (in.)	RIGHT WING, INBOARD X_{W_2} m	RIGHT WING, INBOARD X_{W_2} (in.)	RIGHT WING, MIDWING Y_{W_3} m	RIGHT WING, MIDWING Y_{W_3} (in.)	RIGHT WING, MIDWING X_{W_3} m	RIGHT WING, MIDWING X_{W_3} (in.)
1	111.21	25	111.2	25	1.723	67.83	0.110	4.35	1.720	67.70	0.112	4.40	0.958	37.70	0.112	4.40
2	111.21	25	222.4	50	1.578	62.13	-0.011	-0.45	1.574	61.96	-0.011	-0.45	0.812	31.96	-0.011	-0.45
3	111.21	25	333.6	75	1.278	50.32	0.134	5.28	1.280	50.38	0.134	5.28	0.518	20.38	0.134	5.28
4	111.21	25	444.8	100	1.279	50.34	-0.012	-0.47	1.275	50.19	-0.012	-0.49	0.513	20.19	-0.012	-0.49
5	111.21	25	556.0	125	0.972	38.28	0.151	5.96	0.971	38.24	0.151	5.96	0.209	8.24	0.151	5.96
6	111.21	25	667.2	150	0.975	38.37	-0.013	-0.50	0.971	38.22	-0.013	-0.50	0.209	8.22	-0.013	-0.50
7	222.41	50	889.6	200	0.667	26.26	0.168	6.60	0.669	26.32	0.168	6.60				
8	222.41	50	1112.1	250	0.670	26.36	-0.012	-0.49	0.665	26.20	-0.012	-0.49				
9	222.41	50	1334.5	300	0.362	14.26	0.185	7.30	0.362	14.26	0.185	7.30				
10	222.41	50	1556.9	350	0.363	14.30	-0.012	-0.47	0.362	14.26	-0.012	-0.48				
11	222.41	50	1779.3	400	0.058	2.29	0.203	8.00	0.056	2.21	0.202	7.95				
12	222.41	50	2001.7	450	0.058	2.30	-0.012	-0.47	0.054	2.14	-0.013	-0.51				
13 to 36		*	6005.1	1350												
37	-111.21	-25	5893.9	1325	1.723	67.83	0.110	4.35	1.720	67.70	0.112	4.40	0.958	37.70	0.112	4.40
38	-111.21	-25	5782.7	1300	1.578	62.13	-0.011	-0.45	1.574	61.96	-0.011	-0.45	0.812	31.96	-0.011	-0.45
39	-111.21	-25	5671.5	1275	1.278	50.32	0.134	5.28	1.280	50.38	0.134	5.28	0.518	20.38	0.134	5.28
40	-111.21	-25	5560.3	1250	1.279	50.34	-0.012	-0.47	1.275	50.19	-0.012	-0.49	0.513	20.19	-0.012	-0.49
41	-111.21	-25	5449.1	1225	0.972	38.28	0.151	5.96	0.971	38.24	0.151	5.96	0.209	8.24	0.151	5.96
42	-111.21	-25	5337.9	1200	0.975	38.37	-0.013	-0.50	0.971	38.22	-0.013	-0.50	0.209	8.22	-0.013	-0.50
43	-222.41	-50	5115.5	1150	0.667	26.26	0.168	6.60	0.669	26.32	0.168	6.60				
44	-222.41	-50	4893.0	1100	0.670	26.36	-0.012	-0.49	0.665	26.20	-0.012	-0.49				
45	-222.41	-50	4670.5	1050	0.362	14.26	0.185	7.30	0.362	14.26	0.185	7.30				
46	-222.41	-50	4448.2	1000	0.363	14.30	-0.012	-0.47	0.362	14.26	-0.012	-0.48				
47	-222.41	-50	4225.8	950	0.058	2.29	0.203	8.00	0.056	2.21	0.202	7.95				
48	-222.41	-50	4003.4	900	0.058	2.30	-0.012	-0.47	0.054	2.14	-0.013	-0.51				
49 to 72		+	0	0												

* Repeat steps 1 through 12 two more times.

+ Repeat steps 37 through 48 two more times.

TABLE VII.- WING LOADINGS AND STRAIN-GAGE BRIDGE OUTPUTS FOR SINGLE-POINT APPLIED LOADS

(A) LEFT WING, INBOARD STATION

WING LOADINGS			STRAIN-GAGE BRIDGE OUTPUTS, MILLIVOLTS											
SHEAR, LBS	MOMENT, IN-LBS	TORQUE, IN-LBS	MU 21	MU 22	MU 23	MU 24	MU 25	MU 26	MU 31	MU 32	MU 33	MU 34	MU 35	MU 36
25.00	1695.50	105.75	.009	.684	-.004	.695	.044	.663	.012	.701	-.003	.727	.046	.700
50.00	3248.75	97.50	.047	1.363	.028	1.358	.052	1.250	.055	1.391	.031	1.419	.055	1.318
75.00	4506.75	229.50	.066	1.900	.037	1.872	.113	1.766	.074	1.941	.041	1.957	.115	1.867
100.00	5765.25	217.75	.115	2.493	.084	2.414	.125	2.251	.127	2.556	.066	2.524	.128	2.378
125.00	6722.25	366.75	.136	2.925	.103	2.801	.194	2.659	.147	2.997	.105	2.931	.196	2.811
150.00	7681.50	354.25	.193	3.423	.162	3.219	.208	3.029	.207	3.510	.164	3.369	.210	3.200
200.00	8994.50	684.25	.241	4.060	.213	3.736	.367	3.619	.256	4.164	.214	3.910	.367	3.835
250.00	10307.50	659.75	.362	4.793	.354	4.316	.405	4.109	.379	4.925	.350	4.524	.402	4.350
300.00	11020.50	1024.75	.411	5.198	.410	4.596	.593	4.449	.428	5.346	.406	4.811	.587	4.722
350.00	11735.50	1001.25	.548	5.691	.576	4.920	.635	4.718	.565	5.859	.568	5.154	.627	5.001
400.00	11850.00	1401.25	.580	5.885	.619	5.007	.867	4.714	.598	6.031	.607	5.240	.857	5.001
450.00	11965.00	1377.75	.744	6.085	.820	5.023	.901	4.812	.762	6.271	.610	5.231	.888	5.099
475.00	13660.50	1486.50	.776	6.911	.838	5.711	.940	5.516	.793	7.146	.627	5.970	.930	5.847
500.00	15213.75	1475.25	.815	7.603	.875	6.372	.946	6.103	.836	7.860	.865	6.663	.938	6.463
525.00	16471.75	1607.25	.835	8.175	.892	6.889	1.005	6.618	.957	8.451	.862	7.205	.996	7.006
550.00	17730.25	1595.50	.886	8.800	.945	7.433	1.015	7.105	.911	9.101	.935	7.775	1.007	7.513
575.00	18687.25	1744.50	.910	9.252	.968	7.825	1.085	7.511	.934	9.566	.957	8.185	1.078	7.944
600.00	19646.50	1732.00	.969	9.764	1.031	8.247	1.100	7.884	.994	10.099	1.020	8.629	1.093	8.334
650.00	20959.50	2062.00	1.016	10.426	1.087	8.774	1.264	8.467	1.042	10.763	1.074	9.178	1.256	8.951
700.00	22272.50	2037.50	1.139	11.193	1.233	9.362	1.305	8.970	1.170	11.565	1.217	9.799	1.294	9.476
750.00	22985.50	2402.50	1.188	11.602	1.290	9.647	1.496	9.307	1.218	11.984	1.272	10.091	1.481	9.839
800.00	23700.50	2379.00	1.330	12.124	1.463	9.974	1.541	9.592	1.361	12.520	1.440	10.441	1.523	10.132
850.00	23815.00	2777.00	1.365	12.297	1.505	10.066	1.776	9.594	1.396	12.697	1.479	10.531	1.757	10.135
900.00	23930.00	2755.50	1.528	12.525	1.706	10.061	1.812	9.695	1.560	12.935	1.660	10.522	1.791	10.237
925.00	25625.50	2364.25	1.551	13.308	1.719	10.768	1.859	10.395	1.586	13.750	1.694	11.265	1.841	10.968
950.00	27178.75	2853.00	1.608	14.095	1.772	11.448	1.868	11.020	1.644	14.545	1.746	11.982	1.854	11.613
975.00	28436.75	2985.00	1.626	14.651	1.787	11.969	1.934	11.545	1.664	15.127	1.761	12.531	1.918	12.164
1000.00	29695.25	2973.25	1.681	15.289	1.644	12.524	1.947	12.041	1.722	15.779	1.817	13.119	1.934	12.680
1025.00	30652.25	3122.25	1.700	15.721	1.662	12.913	2.021	12.451	1.742	16.228	1.836	13.527	2.007	13.108
1050.00	31611.50	3109.75	1.772	16.247	1.932	13.367	2.073	12.920	1.817	16.758	1.905	14.026	2.056	13.631
1100.00	32924.50	3439.75	1.821	16.900	1.987	13.894	2.245	13.514	1.866	17.430	1.959	14.585	2.228	14.262
1150.00	34237.50	3415.25	1.947	17.654	2.136	14.500	2.292	14.037	1.998	18.200	2.107	15.236	2.273	14.806
1200.00	34950.50	3780.25	2.001	18.065	2.198	14.799	2.489	14.394	2.049	18.622	2.166	15.552	2.464	15.189
1250.00	35665.50	3756.75	2.136	18.566	2.365	15.129	2.540	14.680	2.189	19.137	2.330	15.908	2.513	15.488
1300.00	35760.00	4156.75	2.173	18.741	2.410	15.225	2.774	14.676	2.225	19.316	2.370	16.000	2.745	15.486
1350.00	35895.00	4133.25	2.351	19.028	2.617	15.282	2.826	14.861	2.403	19.617	2.580	16.069	2.796	15.667

TABLE VII.- CONTINUED

(A) CONCLUDED

WING LOADINGS — STRAIN-GAGE BRIDGE OUTPUTS, MILLIVOLTS

SHEAR, LBS	MOMENT, IN-LBS	TORQUE, IN-LBS	MU 21	MU 22	MU 23	MU 24	MU 25	MU 26	MU 31	MU 32	MU 33	MU 34	MU 35	MU 36
1325.00	34199.50	4024.50	2.352	18.378	2.624	14.597	2.762	14.211	2.403	18.956	2.584	15.352	2.752	14.977
1300.00	32646.25	4035.75	2.320	17.715	2.591	13.941	2.773	13.629	2.366	18.287	2.551	14.665	2.740	14.363
1275.00	31388.25	3903.75	2.308	17.197	2.580	13.438	2.712	13.123	2.350	17.761	2.539	14.137	2.681	13.824
1250.00	30129.75	3915.50	2.263	16.629	2.536	12.906	2.700	12.653	2.306	17.180	2.494	13.560	2.667	13.325
1225.00	29172.75	3766.50	2.243	16.202	2.515	12.526	2.628	12.247	2.285	16.745	2.475	13.162	2.597	12.896
1200.00	28213.50	3779.00	2.193	15.734	2.458	12.114	2.611	11.889	2.232	16.264	2.419	12.752	2.580	12.514
1150.00	26900.50	3449.00	2.153	15.141	2.410	11.610	2.447	11.309	2.190	15.655	2.372	12.225	2.420	11.890
1100.00	25587.50	3473.50	2.037	14.423	2.273	11.036	2.407	10.820	2.072	14.923	2.237	11.622	2.380	11.370
1050.00	24874.50	3108.50	1.996	14.056	2.219	10.767	2.213	10.482	2.030	14.545	2.184	11.380	2.194	10.997
1000.00	24159.50	3132.00	1.864	13.575	2.055	10.450	2.167	10.213	1.895	14.047	2.025	11.007	2.149	10.717
950.00	24045.00	2732.00	1.833	13.416	2.013	10.366	1.935	10.214	1.864	13.887	1.967	10.924	1.919	10.709
900.00	23930.00	2755.50	1.671	13.202	1.812	10.373	1.901	10.117	1.702	13.661	1.786	10.935	1.887	10.612
875.00	22234.50	2646.75	1.654	12.457	1.803	9.650	1.854	9.420	1.683	12.690	1.776	10.209	1.839	9.865
850.00	20681.25	2658.00	1.615	11.749	1.766	9.024	1.848	8.817	1.641	12.157	1.737	9.523	1.831	9.227
825.00	19423.25	2526.00	1.598	11.191	1.749	8.514	1.788	8.292	1.624	11.582	1.721	8.969	1.770	8.664
800.00	18164.75	2537.75	1.549	10.585	1.697	7.974	1.775	7.800	1.574	10.951	1.669	8.424	1.758	8.143
775.00	17207.75	2388.75	1.530	10.150	1.676	7.589	1.705	7.384	1.553	10.500	1.650	8.022	1.687	7.699
750.00	16248.50	2401.25	1.475	9.658	1.614	7.175	1.690	7.012	1.498	9.986	1.587	7.584	1.671	7.306
700.00	14935.50	2071.25	1.431	9.030	1.562	6.659	1.525	6.413	1.452	9.341	1.537	7.045	1.509	6.664
650.00	13622.50	2095.75	1.312	8.297	1.419	6.079	1.485	5.916	1.330	8.574	1.397	6.437	1.471	6.139
600.00	12909.50	1730.75	1.267	7.915	1.365	5.806	1.295	5.579	1.287	8.185	1.345	6.153	1.284	5.767
550.00	12194.50	1754.25	1.132	7.418	1.195	5.489	1.251	5.305	1.149	7.663	1.181	5.618	1.242	5.517
500.00	12080.00	1354.25	1.099	7.252	1.154	5.400	1.018	5.304	1.116	7.497	1.142	5.732	1.011	5.475
450.00	11965.00	1377.75	.933	7.013	.946	5.403	.985	5.197	.949	7.245	.938	5.735	.980	5.369
425.00	10269.50	1269.00	.915	6.267	.942	4.702	.937	4.495	.930	6.468	.929	5.000	.931	4.621
400.00	8716.25	1280.25	.871	5.522	.897	4.038	.931	3.884	.893	5.698	.884	4.304	.922	3.979
375.00	7458.25	1148.25	.849	4.948	.882	3.543	.870	3.358	.861	5.107	.867	3.765	.862	3.417
350.00	6199.75	1160.00	.795	4.316	.828	2.979	.858	2.862	.806	4.455	.814	3.192	.848	2.899
325.00	5242.75	1011.00	.771	3.865	.805	2.588	.786	2.446	.780	3.991	.793	2.761	.777	2.458
300.00	4283.50	1023.50	.711	3.355	.743	2.170	.770	2.072	.720	3.462	.731	2.339	.760	2.067
250.00	2970.50	693.50	.653	2.691	.689	1.646	.606	1.484	.663	2.777	.676	1.769	.599	1.441
200.00	1657.50	718.00	.515	1.911	.542	1.054	.563	.971	.521	1.966	.535	1.165	.559	.907
150.00	944.50	353.00	.458	1.497	.464	.771	.372	.640	.465	1.535	.478	.868	.374	.551
100.00	229.50	376.50	.310	.975	.313	.445	.326	.360	.316	.989	.313	.519	.330	.261
50.00	115.00	-23.50	.269	.789	.270	.351	.096	.363	.276	.799	.272	.426	.102	.262
0.00	0.00	0.00	.101	.554	.068	.353	.061	.260	.106	.547	.069	.433	.070	.159

TABLE VII.- CONTINUED

(B) RIGHT WING, INBOARD STATION

WING LOADINGS			STRAIN-GAGE BRIDGE OUTPUTS, MILLIVOLTS											
SHEAR, LBS	MOMENT, IN-LBS	TORQUE, IN-LBS	MU 1	MU 2	MU 3	MU 4	MU 5	MU 6	MU 11	MU 12	MU 13	MU 14	MU 15	MU 16
25.00	1692.50	110.00	.017	.676	.009	.675	.042	.691	.017	.681	-.009	.690	.044	.682
50.00	3241.50	98.75	.066	1.344	.018	1.319	.047	1.293	.068	1.355	.020	1.349	.051	1.278
75.00	4501.00	230.75	.092	1.869	.025	1.820	.108	1.833	.093	1.903	.027	1.856	.110	1.814
100.00	5755.75	218.50	.154	2.468	.067	2.348	.119	2.324	.155	2.516	.068	2.394	.123	2.296
125.00	6711.75	367.50	.184	2.933	.082	2.724	.187	2.744	.184	2.966	.083	2.779	.189	2.711
150.00	7667.25	355.00	.259	3.474	.141	3.136	.205	3.127	.256	3.516	.140	3.191	.207	3.087
200.00	8983.25	685.00	.314	4.090	.164	3.636	.363	3.733	.311	4.147	.180	3.702	.361	3.688
250.00	10293.25	660.50	.460	4.854	.319	4.211	.406	4.240	.455	4.923	.309	4.261	.403	4.186
300.00	11006.25	1025.50	.515	5.360	.371	4.495	.599	4.605	.508	5.338	.357	4.560	.588	4.553
350.00	11719.25	1001.50	.669	5.766	.534	4.808	.644	4.886	.659	5.833	.512	4.865	.633	4.822
400.00	11829.75	1399.00	.700	5.929	.570	4.896	.884	4.886	.691	6.025	.546	4.970	.871	4.818
450.00	11936.75	1373.50	.874	6.162	.769	4.890	.920	4.988	.864	6.261	.741	4.954	.905	4.913
475.00	13629.25	1483.50	.924	6.963	.776	5.573	.965	5.724	.911	7.083	.751	5.645	.951	5.636
500.00	15178.25	1472.25	.989	7.676	.812	6.230	.974	6.343	.974	7.800	.764	6.306	.959	6.236
525.00	16437.75	1604.25	1.027	8.256	.827	6.736	1.033	6.895	1.013	8.398	.801	6.823	1.018	6.781
550.00	17692.50	1592.00	1.105	8.689	.860	7.283	1.048	7.407	1.088	9.025	.849	7.367	1.032	7.274
575.00	18648.50	1741.00	1.136	9.337	.897	7.663	1.120	7.836	1.121	9.495	.867	7.761	1.102	7.699
600.00	19604.00	1728.50	1.214	9.837	.959	8.073	1.139	8.222	1.199	9.992	.927	8.185	1.120	8.071
650.00	20920.00	2058.50	1.280	10.497	1.008	8.596	1.303	8.837	1.260	10.660	.971	8.707	1.279	8.673
700.00	22230.00	2034.00	1.430	11.219	1.147	9.183	1.347	9.353	1.412	11.390	1.105	9.306	1.323	9.176
750.00	22943.00	2399.00	1.486	11.634	1.198	9.463	1.540	9.712	1.464	11.800	1.151	9.565	1.507	9.531
800.00	23656.00	2375.00	1.643	12.129	1.362	9.793	1.569	10.007	1.621	12.300	1.306	9.928	1.556	9.811
850.00	23766.50	2772.50	1.675	12.309	1.398	9.899	1.833	10.004	1.653	12.480	1.341	10.014	1.798	9.804
900.00	23973.50	2747.00	1.845	12.519	1.592	9.883	1.866	10.107	1.824	12.700	1.533	10.003	1.833	9.901
925.00	25566.00	2857.00	1.888	13.279	1.596	10.583	1.917	10.808	1.863	13.440	1.539	10.707	1.880	10.581
950.00	27115.00	2845.75	1.955	13.989	1.635	11.243	1.930	11.428	1.931	14.160	1.576	11.391	1.895	11.181
975.00	28374.50	2977.75	1.993	14.569	1.647	11.773	1.995	11.978	1.965	14.750	1.587	11.919	1.957	11.721
1000.00	29629.25	2965.50	2.064	15.169	1.695	12.333	2.011	12.488	2.037	15.340	1.635	12.469	1.976	12.201
1025.00	30585.25	3114.50	2.093	15.609	1.711	12.713	2.082	12.908	2.066	15.790	1.649	12.879	2.046	12.621
1050.00	31540.75	3102.00	2.168	16.099	1.768	13.153	2.102	13.298	2.140	16.280	1.705	13.319	2.066	12.991
1100.00	32856.75	3432.00	2.227	16.739	1.813	13.663	2.269	13.908	2.197	16.920	1.746	13.839	2.227	13.581
1150.00	34166.75	3407.50	2.373	17.439	1.947	14.263	2.314	14.428	2.345	17.620	1.677	14.449	2.273	14.081
1200.00	34979.75	3772.50	2.428	17.829	2.001	14.543	2.510	14.788	2.397	18.030	1.925	14.739	2.462	14.441
1250.00	35592.75	3748.50	2.593	18.329	2.161	14.883	2.558	15.088	2.551	18.520	2.078	15.069	2.507	14.711
1300.00	35703.25	4146.00	2.616	18.499	2.201	14.973	2.799	15.078	2.583	18.700	2.114	15.159	2.750	14.701
1350.00	35810.25	4120.50	2.789	18.719	2.396	14.963	2.838	15.188	2.755	18.930	2.307	15.149	2.794	14.791

TABLE VII.- CONTINUED

(B) CONCLUDED

WING LOADINGS			STRAIN-GAGE BRIDGE OUTPUTS, MILLIVOLTS											
SHEAR, LBS	MOMENT, IN-LBS	TORQUE, IN-LBS	MU 1	MU 2	MU 3	MU 4	MU 5	MU 6	MU 11	MU 12	MU 13	MU 14	MU 15	MU 16
1325.00	34117.75	4010.50	2.731	16.129	2.406	14.343	2.617	14.588	2.750	18.330	2.316	14.509	2.763	14.191
1300.00	32568.75	4021.75	2.733	17.469	2.357	13.693	2.815	13.998	2.702	17.660	2.269	13.659	2.759	13.611
1275.00	31309.25	3889.75	2.710	16.949	2.374	13.193	2.759	13.478	2.681	17.140	2.263	13.349	2.705	13.091
1250.00	30054.50	3902.00	2.658	16.399	2.337	12.673	2.752	12.998	2.628	16.580	2.246	12.819	2.695	12.611
1225.00	29098.50	3753.00	2.633	15.989	2.323	12.303	2.685	12.578	2.604	16.170	2.233	12.439	2.630	12.201
1200.00	28143.00	3765.50	2.573	15.539	2.374	11.893	2.670	12.218	2.543	15.710	2.184	12.019	2.614	11.841
1150.00	26827.00	3435.50	2.521	14.949	2.334	11.393	2.509	11.618	2.493	15.120	2.147	11.519	2.457	11.231
1100.00	25517.00	3460.00	2.390	14.269	2.110	10.833	2.466	11.128	2.411	14.430	2.027	10.944	2.417	10.751
1050.00	24804.00	3095.00	2.343	13.901	2.062	10.563	2.474	10.778	2.316	14.060	1.984	10.667	2.231	10.393
1000.00	24091.00	3119.00	2.198	13.439	1.907	10.263	2.229	10.509	2.171	13.590	1.635	10.354	2.198	10.131
950.00	23980.50	2721.50	2.168	13.269	1.871	10.163	1.985	10.508	2.142	13.420	1.603	10.274	1.945	10.131
900.00	23873.50	2747.00	2.000	13.059	1.676	10.173	1.949	10.415	1.973	13.210	1.611	10.291	1.912	10.041
875.00	22181.00	2637.00	1.967	12.329	1.660	9.493	1.906	9.708	1.943	12.470	1.614	9.605	1.870	9.351
850.00	20632.00	2648.25	1.909	11.619	1.650	8.853	1.903	9.104	1.885	11.760	1.562	8.953	1.864	8.751
825.00	19372.50	2516.25	1.875	11.049	1.639	8.353	1.846	8.166	1.853	11.190	1.572	8.447	1.807	8.216
800.00	18117.75	2528.50	1.810	10.439	1.596	7.823	1.833	8.068	1.789	10.570	1.529	7.914	1.795	7.672
775.00	17161.75	2379.50	1.778	9.989	1.579	7.453	1.764	7.639	1.758	10.210	1.513	7.533	1.726	7.307
750.00	16206.25	2392.00	1.710	9.501	1.523	7.047	1.748	7.265	1.691	9.623	1.459	7.124	1.710	6.943
700.00	14890.00	2062.00	1.651	8.861	1.477	6.543	1.562	6.638	1.635	8.971	1.417	6.612	1.549	6.325
650.00	13580.25	2086.50	1.511	8.122	1.345	5.975	1.542	6.136	1.496	8.222	1.289	6.039	1.509	5.833
600.00	12867.25	1721.50	1.459	7.733	1.295	5.705	1.344	5.764	1.445	7.825	1.244	5.765	1.319	5.460
550.00	12154.25	1745.50	1.308	7.232	1.135	5.369	1.298	5.490	1.295	7.313	1.069	5.445	1.275	5.196
500.00	12043.75	1348.00	1.274	7.059	1.097	5.301	1.057	5.488	1.263	7.140	1.056	5.364	1.035	5.197
450.00	11936.75	1373.50	1.099	6.619	.997	5.306	1.022	5.380	1.098	6.893	.860	5.376	1.001	5.099
425.00	10244.25	1263.50	1.061	6.059	.896	4.627	.977	4.658	1.053	6.118	.857	4.667	.957	4.388
400.00	8695.25	1274.75	.994	5.320	.860	3.976	.969	4.035	.986	5.365	.821	4.030	.947	3.783
375.00	7435.75	1142.75	.957	4.735	.849	3.470	.908	3.486	.950	4.771	.811	3.515	.888	3.246
350.00	6181.00	1155.00	.883	4.204	.800	2.933	.894	2.978	.878	4.128	.763	2.974	.874	2.757
325.00	5225.00	1006.00	.846	3.639	.782	2.546	.824	2.547	.843	3.655	.746	2.563	.805	2.336
300.00	4269.50	1018.50	.771	3.132	.723	2.134	.805	2.164	.769	3.140	.689	2.162	.787	1.969
250.00	2953.50	688.50	.702	2.456	.663	1.616	.641	1.535	.703	2.449	.643	1.640	.628	1.349
200.00	1643.50	713.00	.551	1.701	.534	1.034	.597	1.018	.548	1.673	.508	1.046	.586	.856
150.00	930.50	348.00	.489	1.273	.480	.749	.404	.657	.492	1.240	.460	.761	.400	.498
100.00	217.50	372.00	.331	.763	.315	.426	.357	.375	.334	.720	.301	.432	.355	.230
50.00	107.00	-25.50	.292	.574	.275	.333	.116	.373	.297	.526	.266	.345	.116	.231
0.00	0.00	0.00	.119	.346	.076	.338	.079	.269	.123	.267	.070	.357	.052	.135

TABLE VII.- CONCLUDED

(C) RIGHT WING, MIDWING STATION

WING LOADINGS			STRAIN-GAGE BRIDGE OUTPUTS, MILLIVOLTS							
SHEAR, LBS	MOMENT, IN-LBS	TORQUE, IN-LBS	MU 7	MU 8	MU 9	MU 10	MU 17	MU 18	MU 19	MU 20
25.00	942.50	110.00	.024	.704	.063	.672	.016	.703	.074	.642
50.00	1741.50	98.75	.106	1.325	.112	1.225	.096	1.325	.099	1.173
75.00	2251.00	230.75	.147	1.696	.228	1.597	.131	1.691	.206	1.525
100.00	2755.75	218.50	.255	2.096	.228	1.943	.233	2.091	.240	1.656
125.00	2961.75	367.50	.288	2.260	.267	2.071	.262	2.252	.390	1.976
150.00	3167.25	355.00	.436	2.153	.423	2.225	.402	2.398	.419	2.123
175.00	4109.75	465.00	.460	3.112	.519	2.854	.422	3.088	.479	2.728
200.00	4908.75	453.75	.546	3.727	.550	3.408	.500	3.697	.502	3.255
225.00	5418.25	585.75	.586	4.091	.664	3.779	.536	4.058	.610	3.610
250.00	5923.00	573.50	.696	4.487	.703	4.124	.637	4.450	.644	3.937
275.00	6129.00	722.50	.729	4.649	.859	4.251	.666	4.606	.794	4.057
300.00	6334.50	710.00	.877	4.799	.891	4.407	.807	4.752	.822	4.203
325.00	7277.00	820.00	.902	5.494	.954	5.030	.828	5.434	.880	4.800
350.00	8076.00	808.75	.988	6.107	.965	5.583	.906	6.041	.904	5.330
375.00	8585.50	940.75	1.029	6.473	1.098	5.966	.942	6.403	1.011	5.692
400.00	9090.25	928.50	1.139	6.669	1.137	6.312	1.044	6.795	1.045	6.022
425.00	9296.25	1077.50	1.171	7.028	1.291	6.436	1.074	6.950	1.194	6.141
450.00	9501.75	1065.00	1.321	7.177	1.321	6.595	1.216	7.095	1.222	6.267
425.00	8559.25	955.00	1.293	6.493	1.220	5.873	1.193	6.397	1.133	5.592
400.00	7760.25	966.25	1.208	5.875	1.186	5.319	1.115	5.779	1.108	5.063
375.00	7250.75	834.25	1.167	5.507	1.075	4.950	1.079	5.414	1.001	4.710
350.00	6746.00	846.50	1.058	5.111	1.036	4.306	.977	5.071	.967	4.382
325.00	6540.00	697.50	1.025	4.948	.882	4.480	.947	4.860	.818	4.260
300.00	6334.50	710.00	.878	4.798	.849	4.325	.807	4.714	.789	4.116
275.00	5392.00	600.00	.852	4.541	.783	3.698	.765	4.081	.730	3.510
250.00	4593.00	611.25	.766	3.484	.753	3.145	.707	3.408	.706	2.982
225.00	4083.50	479.25	.725	3.114	.639	2.774	.671	3.042	.598	2.626
200.00	3575.75	491.50	.617	2.720	.599	2.429	.570	2.647	.565	2.300
175.00	3372.75	342.50	.584	2.556	.445	2.302	.540	2.488	.416	2.160
150.00	3167.25	355.00	.436	2.407	.414	2.147	.400	2.341	.387	2.033
125.00	2224.75	245.00	.412	1.708	.349	1.519	.360	1.653	.328	1.430
100.00	1425.75	256.25	.327	1.093	.318	.966	.301	1.041	.305	.901
75.00	916.25	124.25	.286	.724	.205	.593	.266	.677	.197	.547
50.00	411.50	136.50	.175	.325	.166	.248	.164	.280	.163	.219
25.00	205.50	-12.50	.145	.160	.012	.119	.135	.121	.014	.096
0.00	0.00	0.00	-.002	.009	-.019	-.036	-.005	-.025	-.013	-.046

TABLE VIII. - LOADING FOR SIMULATED DESIGN CRUISE FLIGHT CONDITION

	APPLIED LOAD (Each Wing)		LOCATION											
			LEFT WING, INBOARD				RIGHT WING, INBOARD				RIGHT WING, MIDWING			
			Y_{W_1}		X_{W_1}		Y_{W_2}		X_{W_2}		Y_{W_3}		X_{W_3}	
	N	(lbs)	m	(in.)	m	(in.)	m	(in.)	m	(in.)	m	(in.)	m	(in.)
1	111.21	25	1.723	67.83	0.110	4.35	1.720	67.70	0.112	4.40	0.958	37.70	0.112	4.40
2	111.21	25	1.578	62.13	-0.011	-0.45	1.574	61.96	-0.011	-0.45	0.812	31.96	-0.011	-0.45
3	111.21	25	1.483	58.40	0.123	4.85	1.482	58.35	0.123	4.85	0.720	28.35	0.123	4.35
4	111.21	25	1.279	50.34	-0.012	-0.47	1.275	50.19	-0.-12	-0.49	0.513	20.19	-0.012	-0.49
5	111.21	25	1.278	50.32	0.134	5.28	1.280	50.38	0.134	5.28	0.518	20.38	0.134	5.28
6	111.21	25	1.127	44.37	-0.012	-0.49	1.124	44.25	-0.012	-0.49	0.362	14.25	-0.012	-0.49
7	111.21	25	1.128	44.39	0.143	5.63	1.127	44.36	0.143	5.63	0.365	14.36	0.143	5.63
8	111.21	25	0.975	38.37	-0.013	-0.50	0.971	38.22	-0.013	-0.50	0.209	8.22	-0.013	-0.50
9	111.21	25	0.983	38.70	0.206	8.10	0.980	38.60	0.206	8.10	0.218	8.60	0.206	8.10
10	111.21	25	0.822	32.35	-0.013	-0.50	0.818	32.21	-0.013	-0.50	0.056	2.21	-0.013	-0.50
11	111.21	25	0.821	32.31	0.160	6.30	0.820	32.27	0.160	6.30	0.058	2.27	0.160	6.30
12	111.21	25	0.783	30.83	0.161	6.35	0.782	30.77	0.163	6.40	0.020	0.77	0.163	6.40
13	111.21	25	0.670	26.36	-0.012	-0.49	0.665	26.20	-0.012	-0.49				
14	111.21	25	0.678	26.69	0.243	9.55	0.673	26.50	0.241	9.48				
15	111.21	25	0.551	21.82	-0.013	-0.50	0.550	21.66	-0.013	-0.50				
16	111.21	25	0.554	21.80	0.174	6.87	0.553	21.77	0.173	6.83				
17	111.21	25	0.478	18.80	-0.011	-0.45	0.474	18.66	-0.013	-0.50				
18	111.21	25	0.440	17.33	0.182	7.15	0.439	17.29	0.182	7.15				
19	111.21	25	0.363	14.30	-0.012	-0.47	0.361	14.20	-0.013	-0.50				
20	111.21	25	0.362	14.26	0.185	7.30	0.362	14.26	0.185	7.30				
21	111.21	25	0.248	9.78	-0.011	-0.45	0.245	9.64	-0.013	-0.50				
22	111.21	25	0.249	9.80	0.191	7.52	0.247	9.71	0.192	7.54				
23	111.21	25	0.173	6.80	-0.011	-0.45	0.168	6.61	-0.012	-0.48				
24	111.21	25	0.134	5.26	0.198	7.80	0.133	5.24	0.197	7.77				
25	111.21	25	0.058	2.30	-0.012	-0.47	0.054	2.14	-0.013	-0.51				
26	111.21	25	0.058	2.29	0.203	8.00	0.056	2.21	0.202	7.95				
27	111.21	25	-0.017	-0.67	-0.011	-0.45	-0.021	-0.82	-0.012	-0.48				
28	111.21	25	-0.079	-3.12	0.232	9.14	-0.077	-3.03	0.234	9.20				
29	155.69	35	-0.093	-3.68	-0.011	-0.45	-0.099	-3.88	-0.012	-0.49				
30	66.72	15	-0.165	-6.50	0.236	9.30	-0.162	-6.39	0.239	9.40				
31	111.21	25	-0.209	-8.21	-0.011	-0.45	-0.213	-8.38	-0.013	-0.50				
32	111.21	25	-0.246	-9.70	0.242	9.51	-0.245	-9.64	0.243	9.58				

TABLE IX. - LOADING FOR SIMULATED DESIGN STRENGTH FLIGHT CONDITION (2.5 g MANEUVER).

	APPLIED LOAD (Each Wing)		LOCATION													
			LEFT WING, INBOARD				RIGHT WING, INBOARD						RIGHT WING, MIDWING			
			Y_{W_1}		X_{W_1}		Y_{W_2}		X_{W_2}		Y_{W_3}		X_{W_3}			
	N	(lbs)	m	(in.)	m	(in.)	m	(in.)	m	(in.)	m	(in.)	m	(in.)		
1	111.21	25	1.667	65.63	0.048	1.90	1.666	65.58	0.050	1.95	0.904	35.58	0.050	1.95		
2	444.82	100	1.578	62.13	-0.011	-0.45	1.574	61.96	-0.011	-0.45	0.812	31.96	-0.011	-0.45		
3	111.21	25	1.400	55.13	0.128	5.05	1.400	55.12	0.129	5.09	0.638	25.12	0.129	5.09		
4	222.41	50	1.447	56.98	-0.010	-0.40	1.444	56.86	-0.011	-0.45	0.682	26.86	-0.011	-0.45		
5	333.62	75	1.275	50.19	-0.012	-0.49	1.275	50.19	-0.012	-0.49	0.513	20.19	-0.012	-0.49		
6	111.21	25	1.280	50.38	0.134	5.28	1.280	50.38	0.134	5.28	0.518	20.38	0.134	5.28		
7	333.62	75	1.165	45.88	-0.012	-0.48	1.162	45.74	-0.012	-0.48	0.400	15.74	-0.012	-0.48		
8	111.21	25	1.128	44.39	0.143	5.63	1.127	44.36	0.143	5.63	0.365	14.36	0.143	5.63		
9	222.41	50	1.050	41.35	-0.013	-0.50	1.047	41.21	-0.013	-0.50	0.285	11.21	-0.013	-0.50		
10	222.41	50	1.011	39.80	0.148	5.83	1.009	39.73	0.149	5.88	0.247	9.73	0.149	5.88		
11	444.82	100	0.860	33.85	-0.013	-0.50	0.857	33.74	-0.013	-0.52	0.095	3.74	-0.013	-0.52		
12	222.41	50	0.857	33.73	0.158	6.23	0.857	33.75	0.158	6.23	0.095	3.75	0.158	6.23		
13	333.62	75	0.707	27.83	-0.013	-0.50	0.704	27.70	-0.013	-0.50						
14	333.62	75	0.705	27.75	0.166	6.53	0.707	27.82	0.166	6.53						
15	333.62	75	0.592	23.30	-0.013	-0.50	0.589	23.18	-0.013	-0.50						
16	222.41	50	0.554	21.80	0.174	6.87	0.554	21.80	0.171	6.75						
17	333.62	75	0.439	17.30	-0.012	-0.48	0.435	17.12	-0.012	-0.48						
18	333.62	75	0.401	15.77	0.182	7.15	0.401	15.78	0.183	7.20						
19	333.62	75	0.325	12.80	-0.012	-0.47	0.320	12.60	-0.012	-0.49						
20	222.41	50	0.286	11.27	0.189	7.45	0.284	11.19	0.190	7.48						
21	333.62	75	0.211	8.30	-0.011	-0.45	0.207	8.13	-0.013	-0.50						
22	222.41	50	0.172	6.77	0.196	7.70	0.171	6.72	0.197	7.74						
23	333.62	75	0.058	2.30	-0.012	-0.47	0.054	2.14	-0.013	-0.51						
24	222.41	50	0.058	2.29	0.203	8.00	0.056	2.21	0.202	7.95						
25	333.62	75	-0.055	-2.17	-0.011	-0.45	-0.060	-2.35	-0.013	-0.50						
26	222.41	50	-0.049	-1.92	0.230	9.05	-0.048	-1.89	0.232	9.13						
27	333.62	75	-0.169	-6.67	-0.011	-0.45	-0.174	-6.85	-0.013	-0.50						
28	222.41	50	-0.165	-6.50	0.236	9.30	-0.168	-6.60	0.236	9.30						
29	111.21	25	-0.209	-8.21	-0.011	-0.45	-0.213	-8.38	-0.013	-0.50						
30	111.21	25	-0.246	-9.70	0.242	9.51	-0.249	-9.80	0.240	9.45						

TABLE X.- DESIGN CRUISE AND MANEUVER FLIGHT CONDITION WING LOADINGS AND ASSOCIATED STRAIN GAGE BRIDGE OUTPUTS

Design Flight Condition	Wing loadings: Shear, N (lbs.)	Wing loadings: Bending Moment, N-m (in.-lb.)	Wing loadings: Torsional Moment, N-m (in.-lb.)	Strain-gage bridge outputs, millivolts, for -											
		Left wing, inboard		μ_{21}	μ_{22}	μ_{23}	μ_{24}	μ_{25}	μ_{26}	μ_{31}	μ_{32}	μ_{33}	μ_{34}	μ_{35}	μ_{36}
Cruise	650	18698	2234	1.217	9.356	1.129	7.648	1.405	7.639	1.242	9.666	1.089	8.013	1.377	8.117
Maneuver	1450	43042	3148	3.134	22.135	2.972	17.932	2.472	17.365	3.234	22.895	2.906	16.798	2.424	18.344
		Right wing, inboard		μ_{1}	μ_{2}	μ_{3}	μ_{4}	μ_{5}	μ_{6}	μ_{11}	μ_{12}	μ_{13}	μ_{14}	μ_{15}	μ_{16}
Cruise	650	18634	2251	1.424	9.404	1.037	7.455	1.416	7.803	1.412	9.559	0.976	7.570	1.375	7.678
Maneuver	1450	42910	3139	3.595	21.840	2.724	17.673	2.483	17.550	3.601	22.122	2.613	17.867	2.398	17.167
		Right wing, midwing		μ_{7}	μ_{8}	μ_{9}	μ_{10}	μ_{17}	μ_{18}	μ_{19}	μ_{20}				
Cruise	300	4732	963	0.810	3.607	1.082	3.049	0.763	3.542	1.106	2.897				
Maneuver	650	11228	837	2.398	8.402	1.645	7.633	2.237	8.291	1.491	7.222				

TABLE XI.- SUMMARY OF SELECTED STRAIN-GAGE BRIDGES, LOAD COEFFICIENTS, PROBABLE ERRORS, AND ACCURACY EVALUATION

A. Left Wing, Inboard Station.

Load measurement	Selected bridges	Load coefficient ± probable error		Average wing calibration loading	Probable error of load estimate	Multiple correlation coefficient
V, N (lb)	23	762.0 ± 37.8 N/mV	(171.3 ± 8.5 lb/mV)	2522 N (567 lbs)	±56 N (±12.5 lbs)	.99985
	35	693.0 ± 41.4 N/mV	(155.8 ± 9.3 lb/mV)			
	36	132.1 ± 4.0 N/mV	(29.7 ± 0.9 lb/mV)			
M, N-m (in.-lb)	23	-121.1 ± 9.8 N-m/mV	(-1071.6 ± 87.0 in.-lb/mV)	1704 N-m (15084 in.-lbs)	±28 N-m (±244.6 in.-lbs)	.99992
	36	279.5 ± 1.7 N-m/mV	(2473.6 ± 14.7 in.-lb/mV)			
T, N-m (in.-lb)	23	- 79.5 ± 4.3 N-m/mV	(-703.4 ± 38.3 in.-lb/mV)	196 N-m (1737 in.-lbs)	±6 N-m (±56.6 in.-lbs)	.99967
	35	220.1 ± 4.7 N-m/mV	(1947.8 ± 41.8 in.-lb/mV)			
	36	4.1 ± 0.4 N-m/mV	(36.7 ± 3.9 in.-lb/mV)			

TABLE XI.- CONTINUED

B. Right Wing, Inboard Station.

Load measurement	Selected bridges	Load coefficient ± probable error		Average wing calibration loading	Probable error of load estimate	Multiple correlation coefficient
V, N (lb)	13	800.2 ± 33.8 N/mV	(179.9 ± 7.6 lb/mV)	2122 N (477 lbs)	±62 N-m (±13.9 lbs)	.99976
	4	141.9 ± 4.0 N/mV	(31.9 ± 0.9 lb/mV)			
	15	708.6 ± 31.6 N/mV	(159.3 ± 7.1 lb/mV)			
M, N-m (in.-lb)	13	-129.1 ± 11.7 N-m/mV	(-1142.3 ± 103.9 in.-lb/mV)	1435 N-m (12700 in.-lbs)	±32 N-m (±287.1 in.-lbs)	.99986
	4	288.7 ± 1.8 N-m/mV	(2555.2 ± 16.3 in.-lb/mV)			
T, N-m (in.-lb)	13	- 86.9 ± 3.8 N-m/mV	(-769.3 ± 33.6 in.-lb/mV)	165 N-m (1458.7 in.-lbs)	±7 N-m (±61.7 in.-lbs)	.99903
	4	4.4 ± 0.5 N-m/mV	(39.3 ± 4.0 in.-lb/mV)			
	15	214.6 ± 3.6 N-m/mV	(1894.6 ± 31.6 in.-lb/m/V)			

TABLE XI.- CONCLUDED

C. Right Wing, Midwing Station.

Load measurement	Selected bridges	Load coefficient ± probable error		Average wing calibration loading	Probable error of load estimate	Multiple correlation coefficient
V, N (lb)	7	593.8 ± 15.6 N/mV	(133.5 ± 3.5 lb/mV)	792 N (178.1 lbs)	±24 N (±54 lbs)	.99971
	18	79.2 ± 3.6 N/mV	(17.8 ± 0.8 lb/mV)			
	9	512.4 ± 15.6 N/mV	(115.2 ± 3.5 lb/mV)			
M, N-m (in.-lb)	18	46.9 ± 12.5 N-m/mV	(415.5 ± 110.5 in.-lb/mV)	409 N-m (3616.9 in.-lbs)	±14 N-m (126.0 in.-lbs)	.99964
	9	29.7 ± 9.7 N-m/mV	(263.2 ± 85.6 in.-lb/mV)			
	10	107.7 ± 12.7 N-m/mV	(952.9 ± 112.6 in.-lb/mV)			
T, N-m (in.-lb)	7	-41.2 ± 3.1 N-m/mV	(-364.8 ± 27.1 in.-lb/mV)	48 N-m (423.4 in.-lbs)	±5 N-m (±40.1 in.-lbs)	.99754
	18	-25.2 ± 4.0 N-m/mV	(-223.3 ± 35.5 in.-lb/mV)			
	9	123.9 ± 3.2 N-m/mV	(1096.5 ± 28.4 in.-lb/mV)			
	10	29.3 4.2 N-m/mV	(259.1 ± 36.9 in.-lb/mV)			

TABLE XII.- EVALUATION OF PREDICTED LOADS FOR TWO SIMULATED FLIGHT LOADINGS

	Design cruise simulated wing loading						Design maneuver simulated wing loading					
	Shear		Bending moment		Torque		Shear		Bending moment		Torque	
	N	(lbs.)	N-m	(in. lbs.)	N-m	(in. lbs.)	N	(lbs.)	N-m	(in.lbs.)	N-m	(in. lbs.)
	Left wing, inboard station						Left wing, inboard station					
Calculated	2886.9	(649)	2132	(18868)	247	(2186)	6369.9	(1432)	4767	(42195)	373	(3304)
Actual	2891.3	(650)	2113	(18698)	264	(2334)	6449.9	(1450)	4863	(43042)	356	(3148)
Difference	-4.4	(-1)	19	(170)	-17	(-148)	-80.1	(-18)	-96	(-847)	18	(156)
% - Error	-0.2	-0.2	0.9	0.9	-6.3	-6.3	-1.2	-1.2	-2.0	-2.0	5.0	5.0
	Right wing, inboard station						Right wing, inboard station					
Calculated	2811.3	(632)	2018	(17864)	243	(2147)	6294.2	(1415)	4750	(42046)	365	(3228)
Actual	2891.3	(650)	2105	(18634)	254	(2251)	6449.9	(1450)	4848	(42910)	355	(3139)
Difference	-80.1	(-18)	-87	(-770)	-11	(-104)	-155.7	(-35)	-98	(-864)	10	(89)
% - Error	-2.8	-2.8	4.1	4.1	-4.6	-4.6	-2.4	-2.4	-2.0	-2.0	2.8	2.8
	Right wing, midwing station						Right wing, midwing station					
Calculated	1316.7	(296)	527	(4662)	101	(890)	2926.9	(658)	1260	(11151)	119.22	(1055)
Actual	1334.5	(300)	535	(4732)	108	(963)	2891.3	(650)	1269	(11228)	94.56	(837)
Difference	-17.8	(-4)	-8	(-70)	-7	(-73)	35.6	(8)	-9	(-77)	25	(218)
% - Error	-1.3	-1.3	-1.5	-1.5	-7.6	-7.6	1.2	1.2	-0.7	-0.7	26.0	26.0

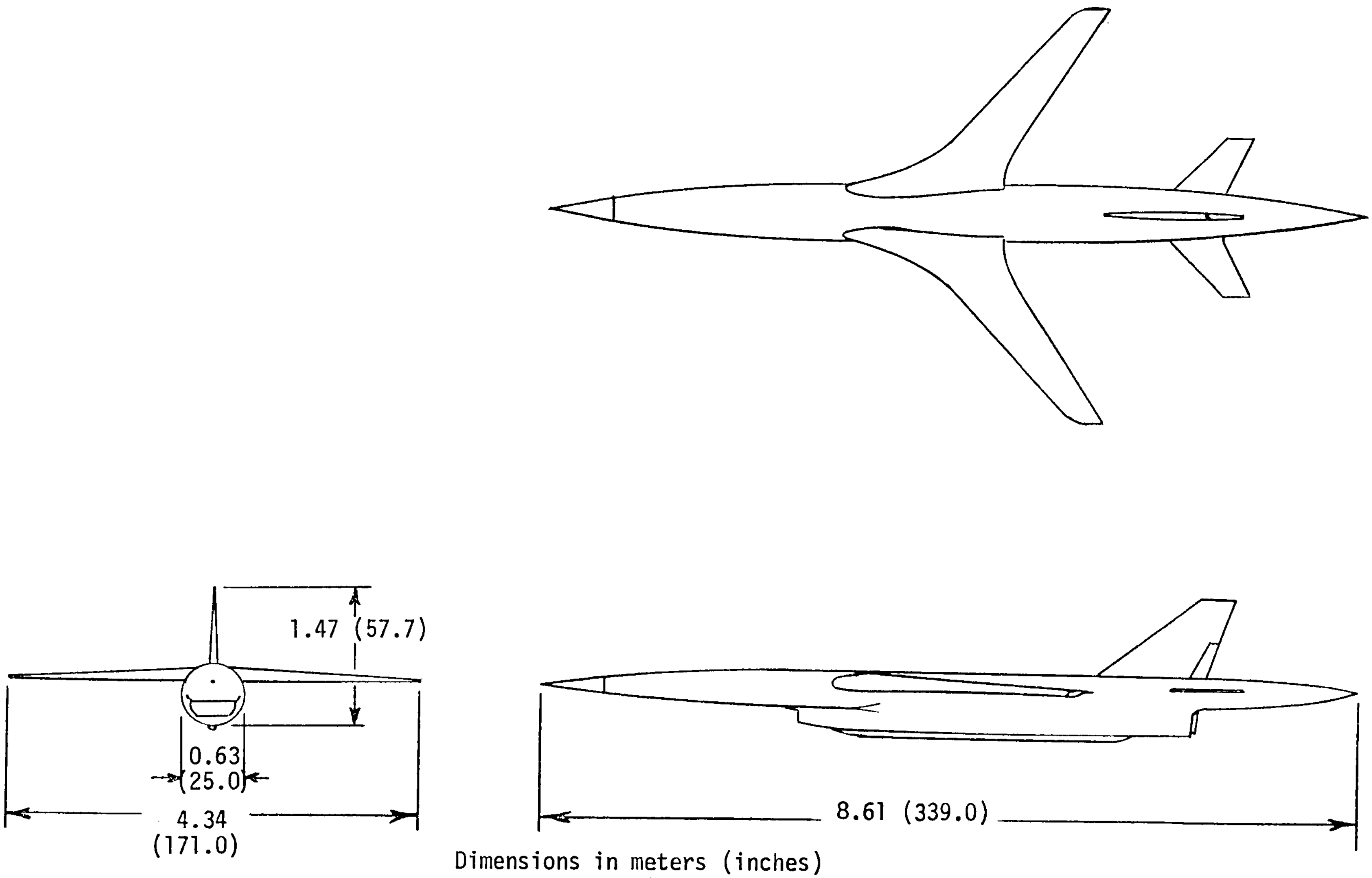


Figure 1.- General arrangement of BQM-34F drone aircraft with ARW-1 wing.

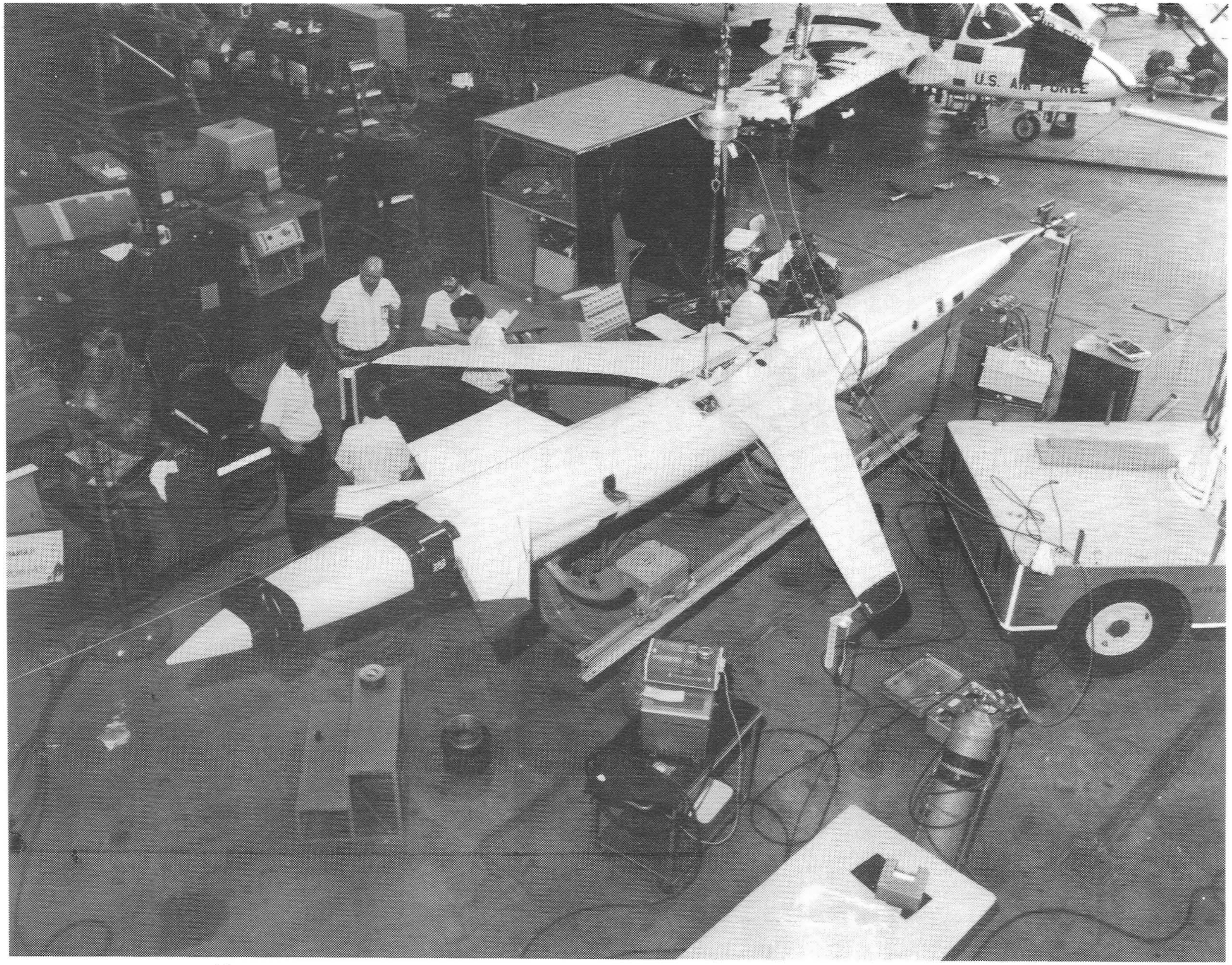


Figure 2.- Photograph of the aircraft and wing during assembly checkout.

NASA
L-77-3537

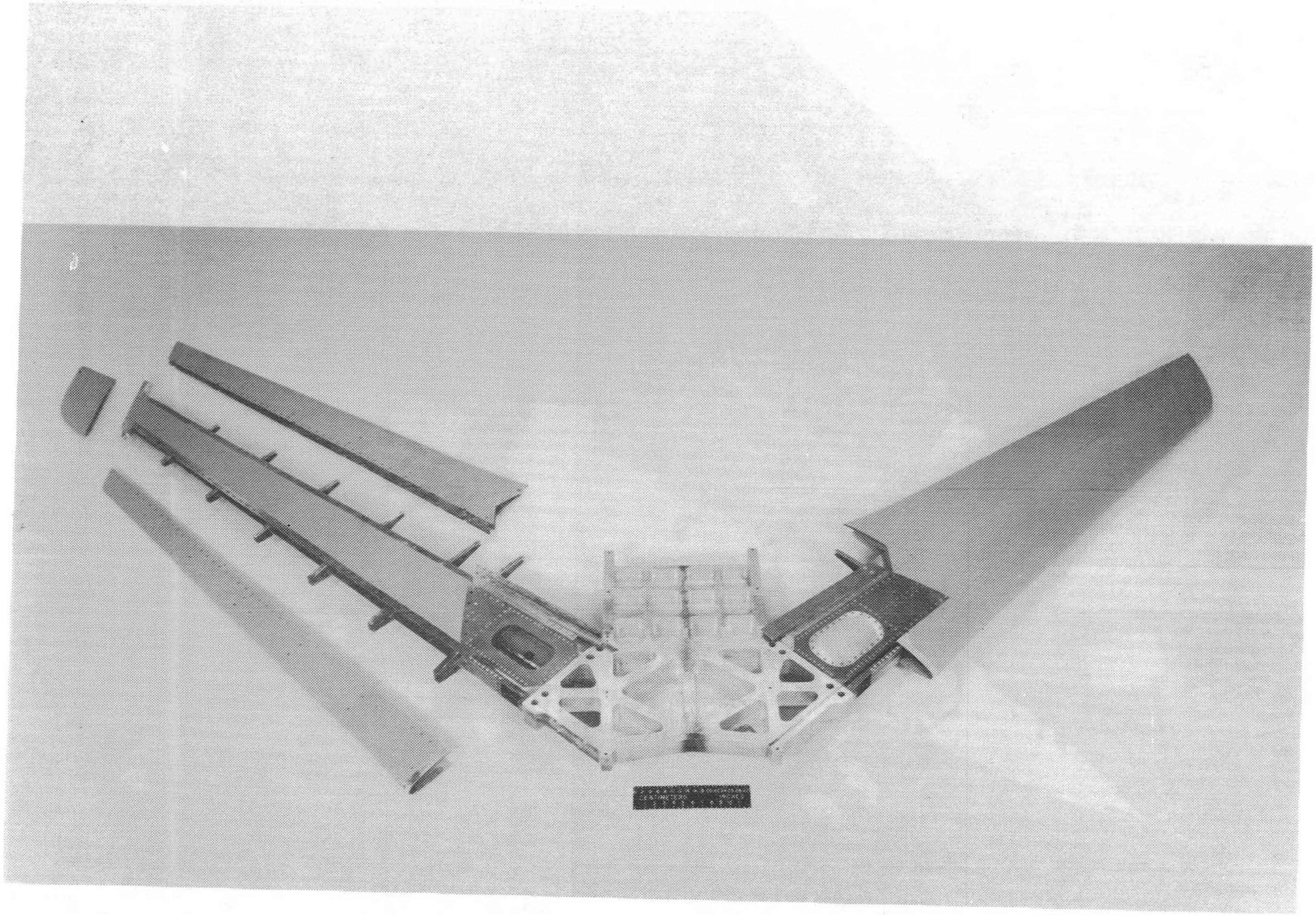


Figure 3.- Photograph of wing.

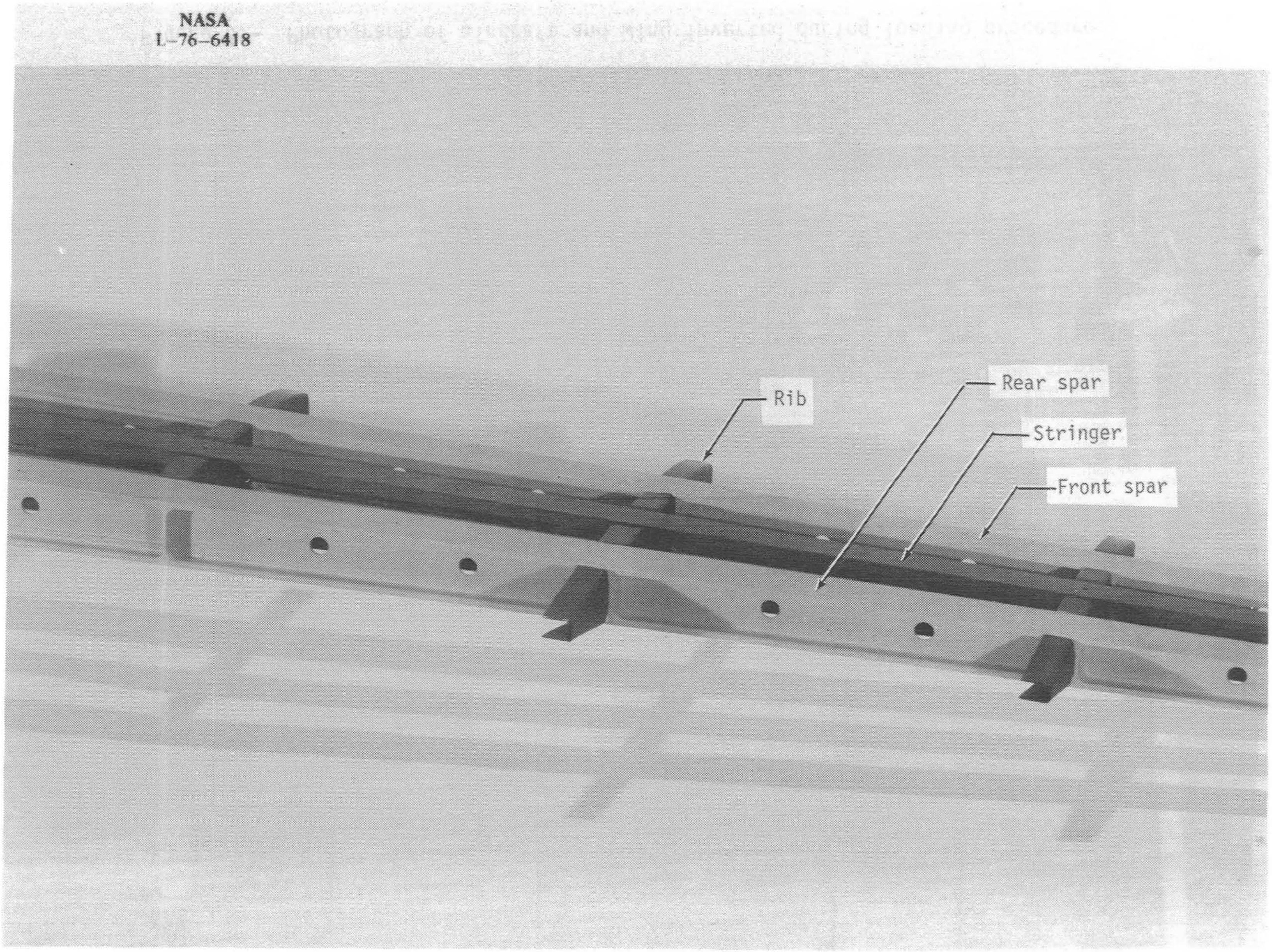


Figure 4.- Photograph of primary wing structure.

NASA
L-78-5981

Figure 5.- Photograph of aircraft and wing inverted during loading procedure.

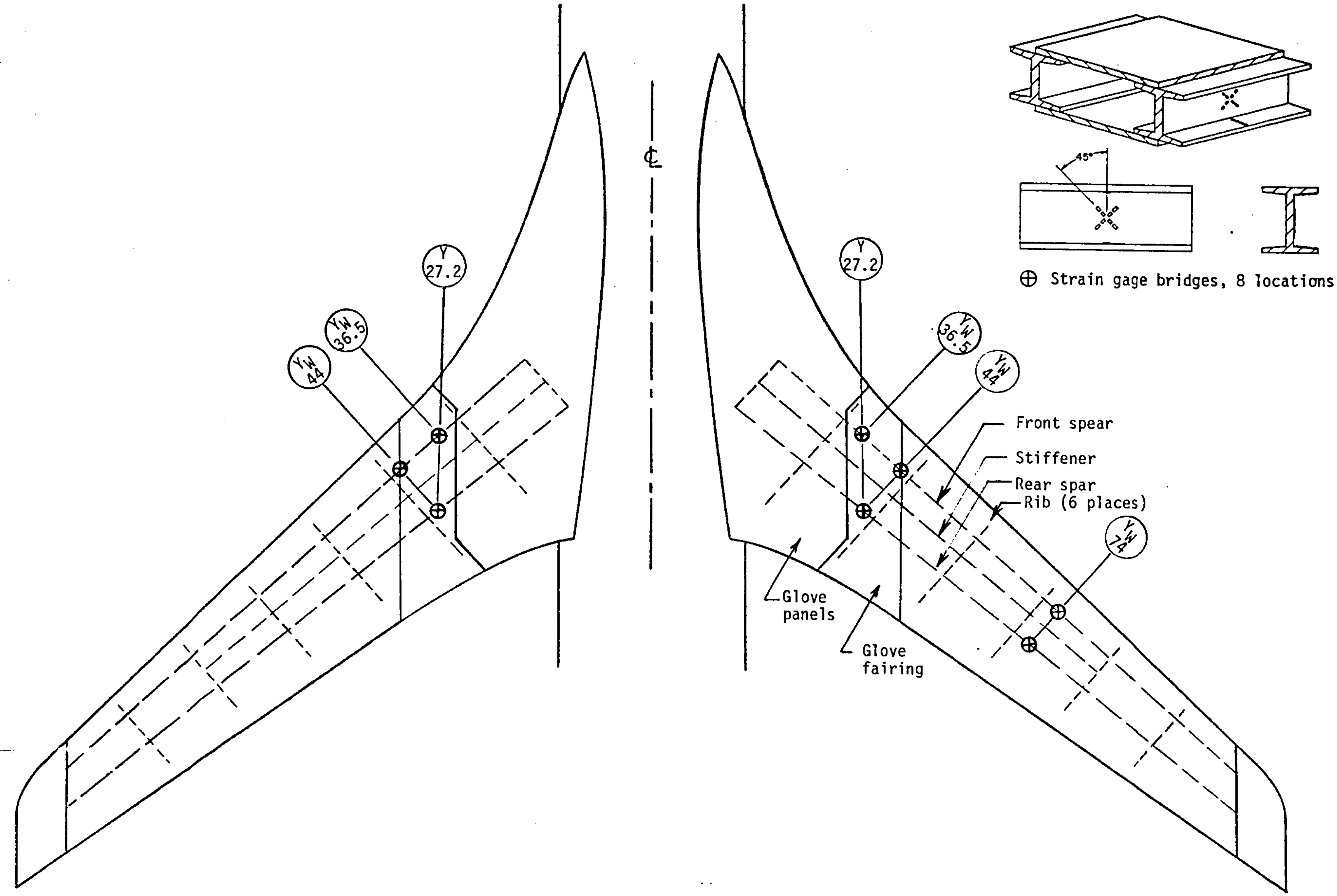
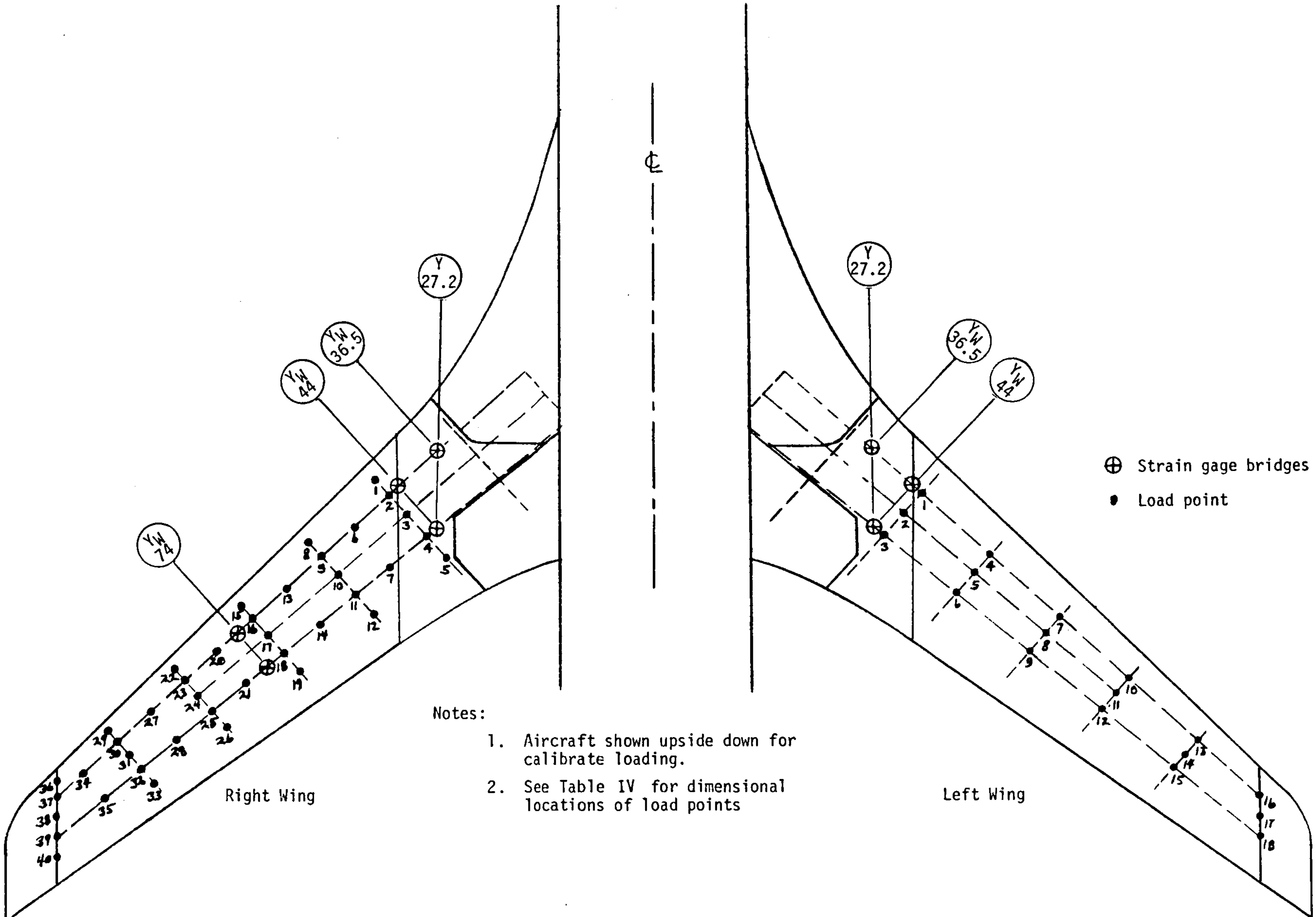


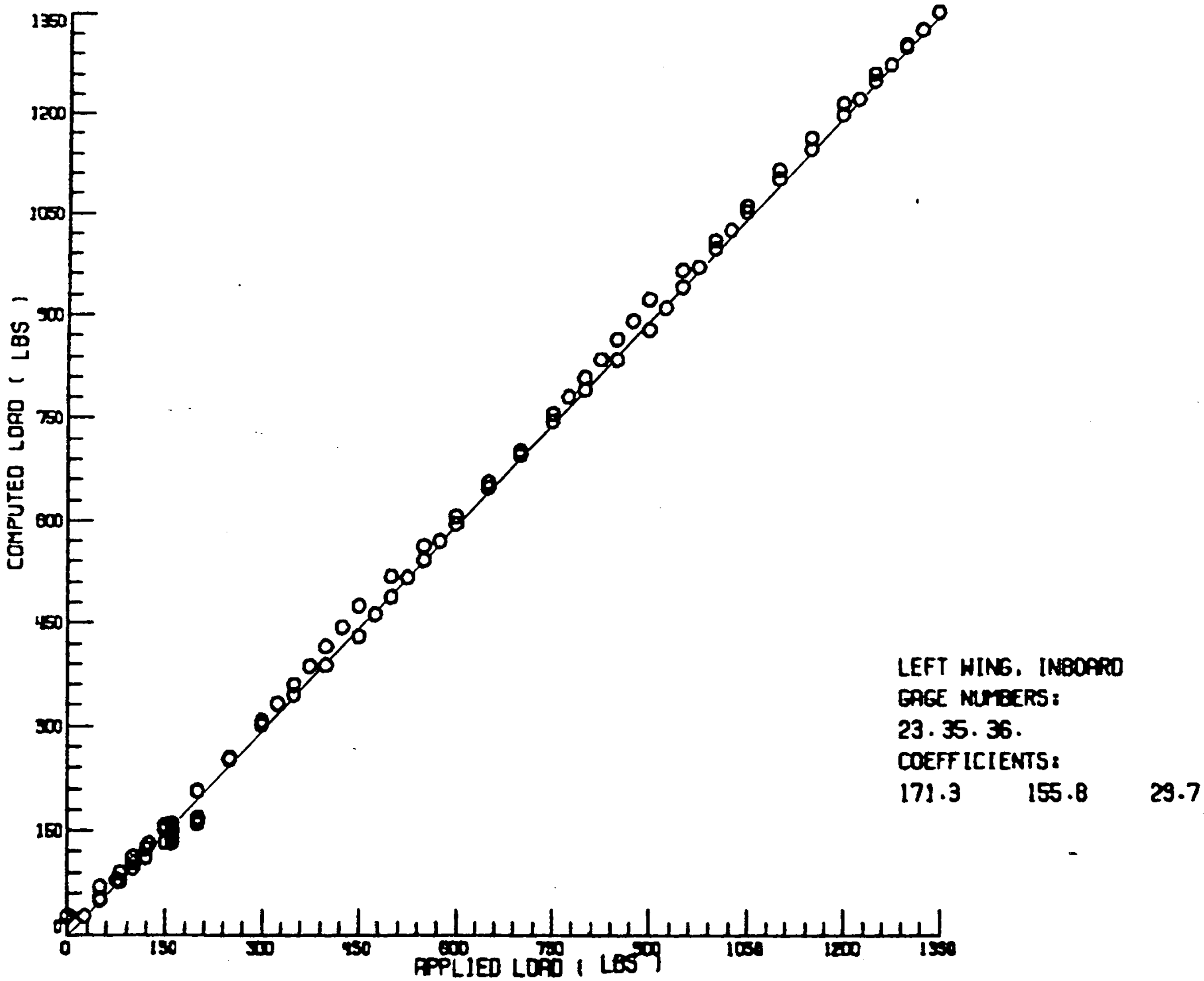
Figure 6.- Strain gage bridge locations.



Notes:

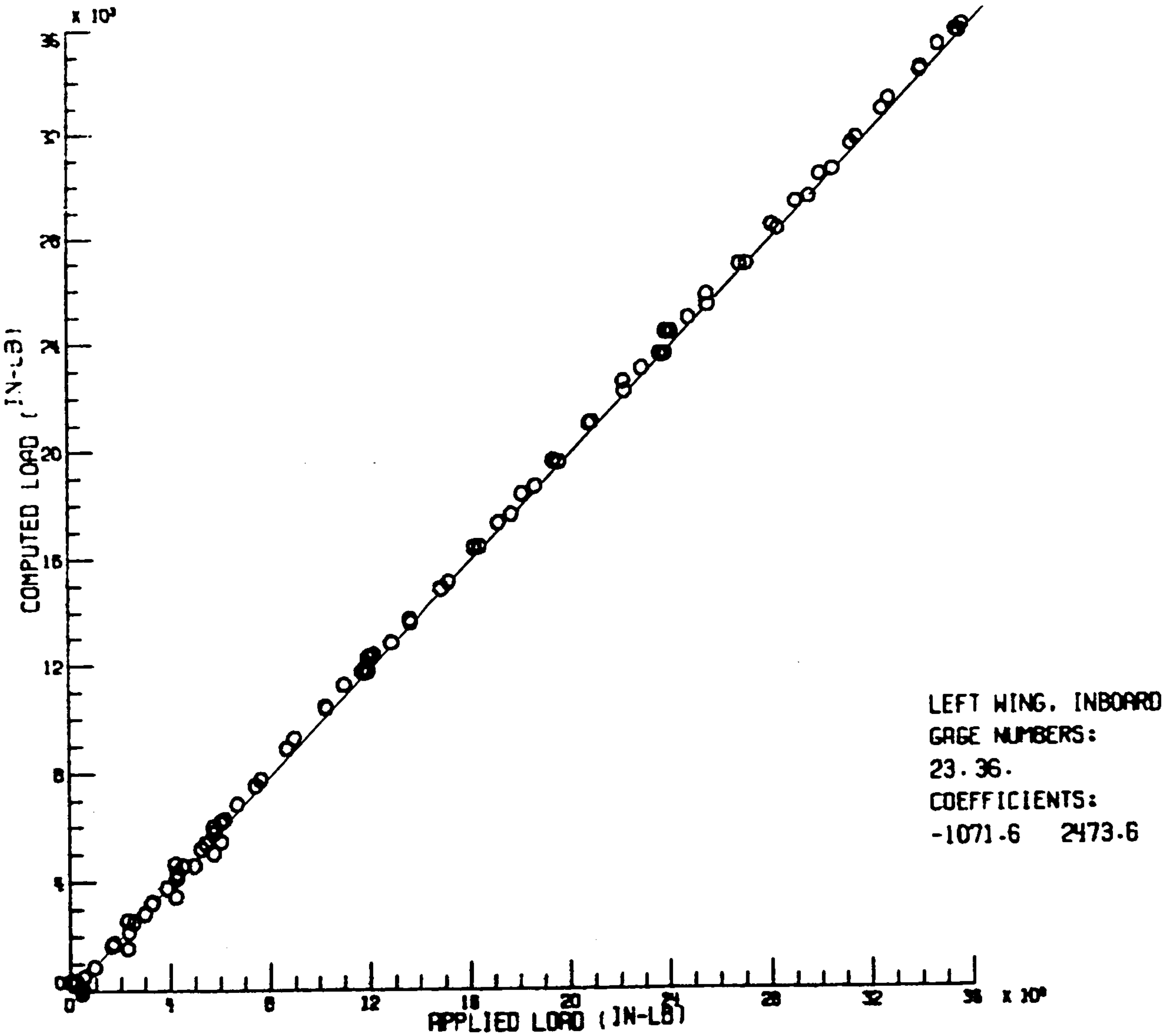
1. Aircraft shown upside down for calibrate loading.
2. See Table IV for dimensional locations of load points

Figure 7.- Point and multipoint calbirate loading locations.



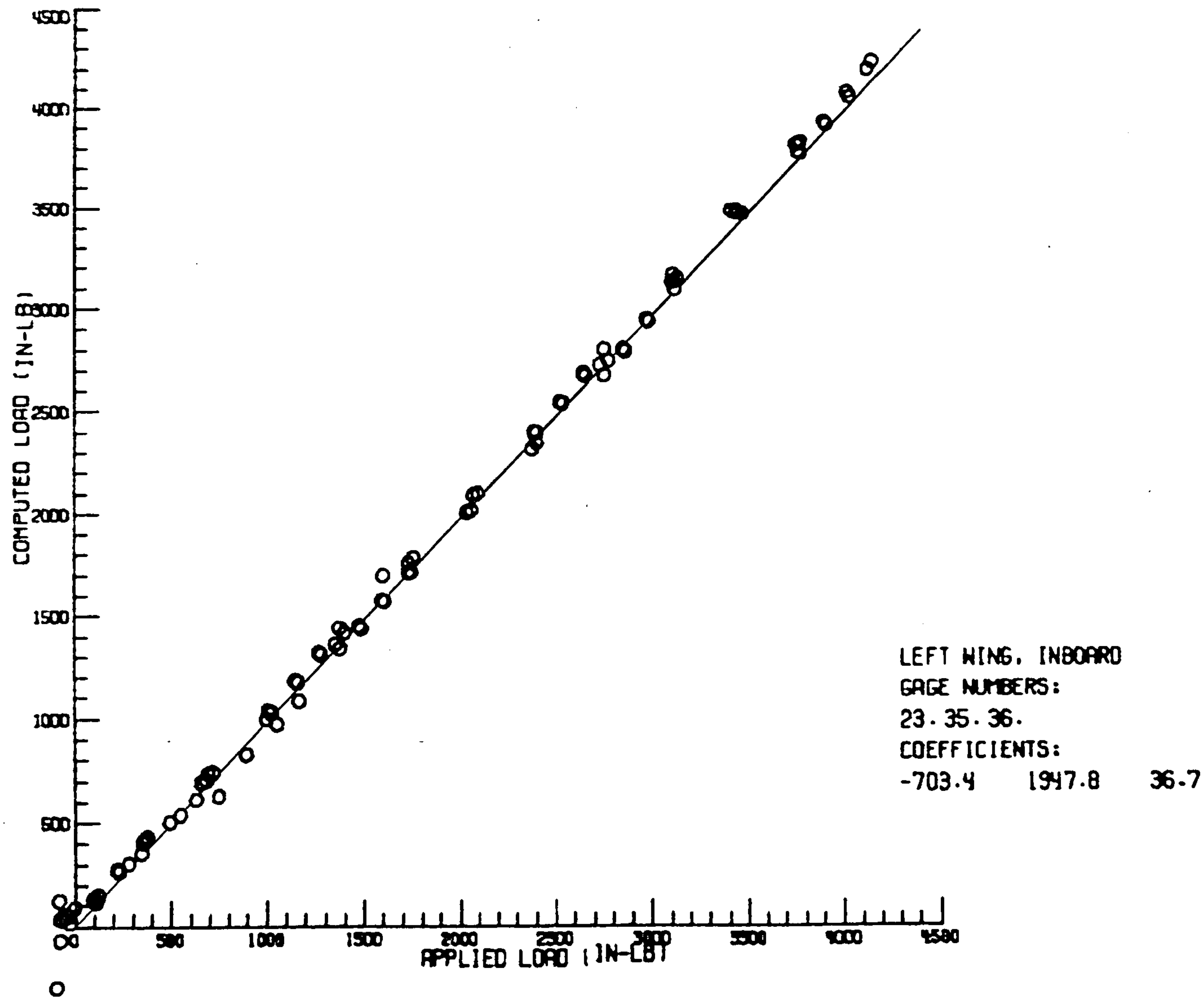
SHEAR, COMBINED LOADINGS

Figure 8.- Correlation of computed shear loads with applied calibration shear loads for the left wing inboard station.



BENDING MOMENT, COMBINED LOADINGS

Figure 9.- Correlation of computed bending moment loads with applied calibration bending moment loads for the left wing inboard station.



TORQUE, COMBINED LOADINGS

Figure 10.- Correlation of computed torque loads with applied calibration torque loads for the left wing inboard station.

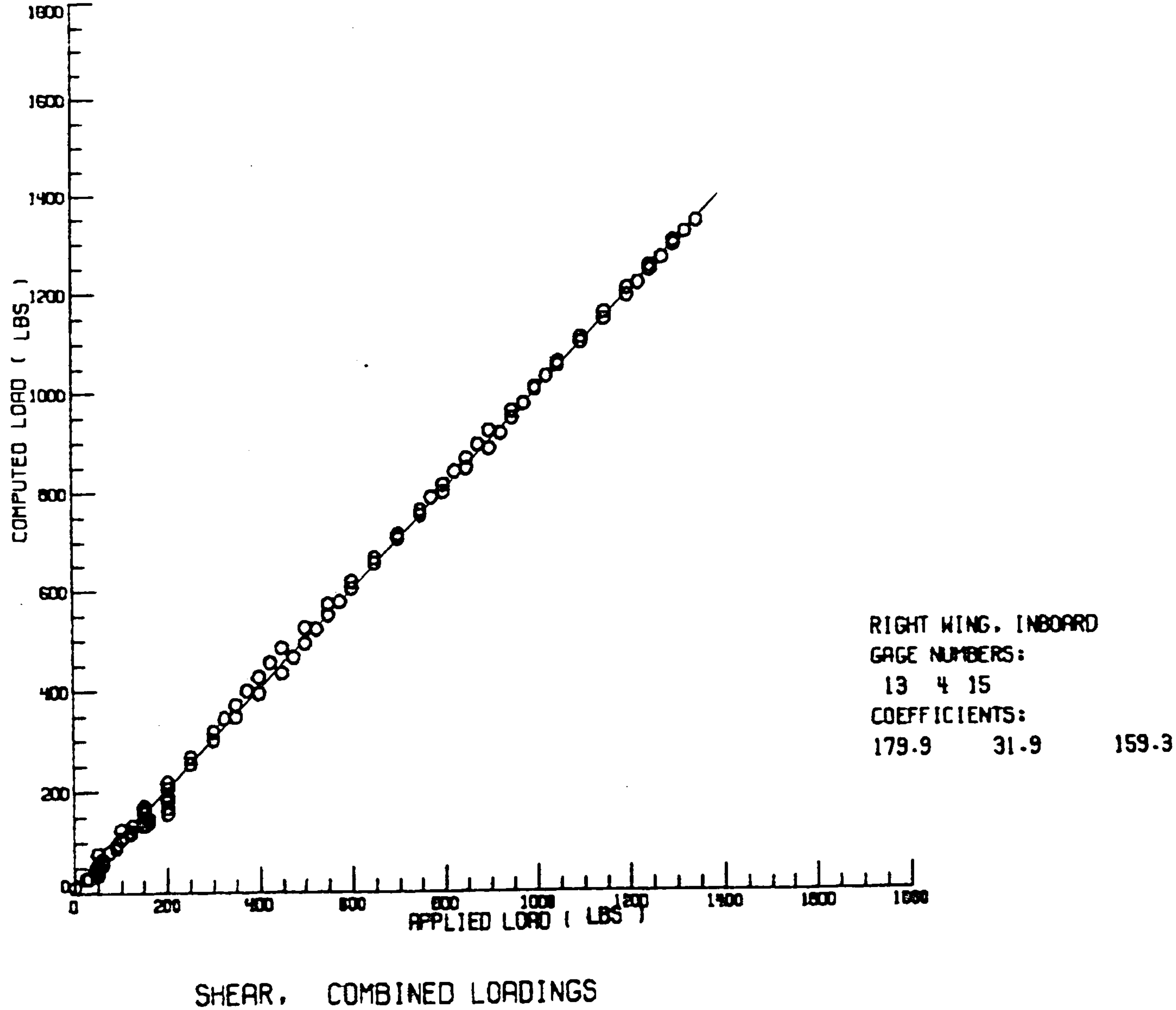
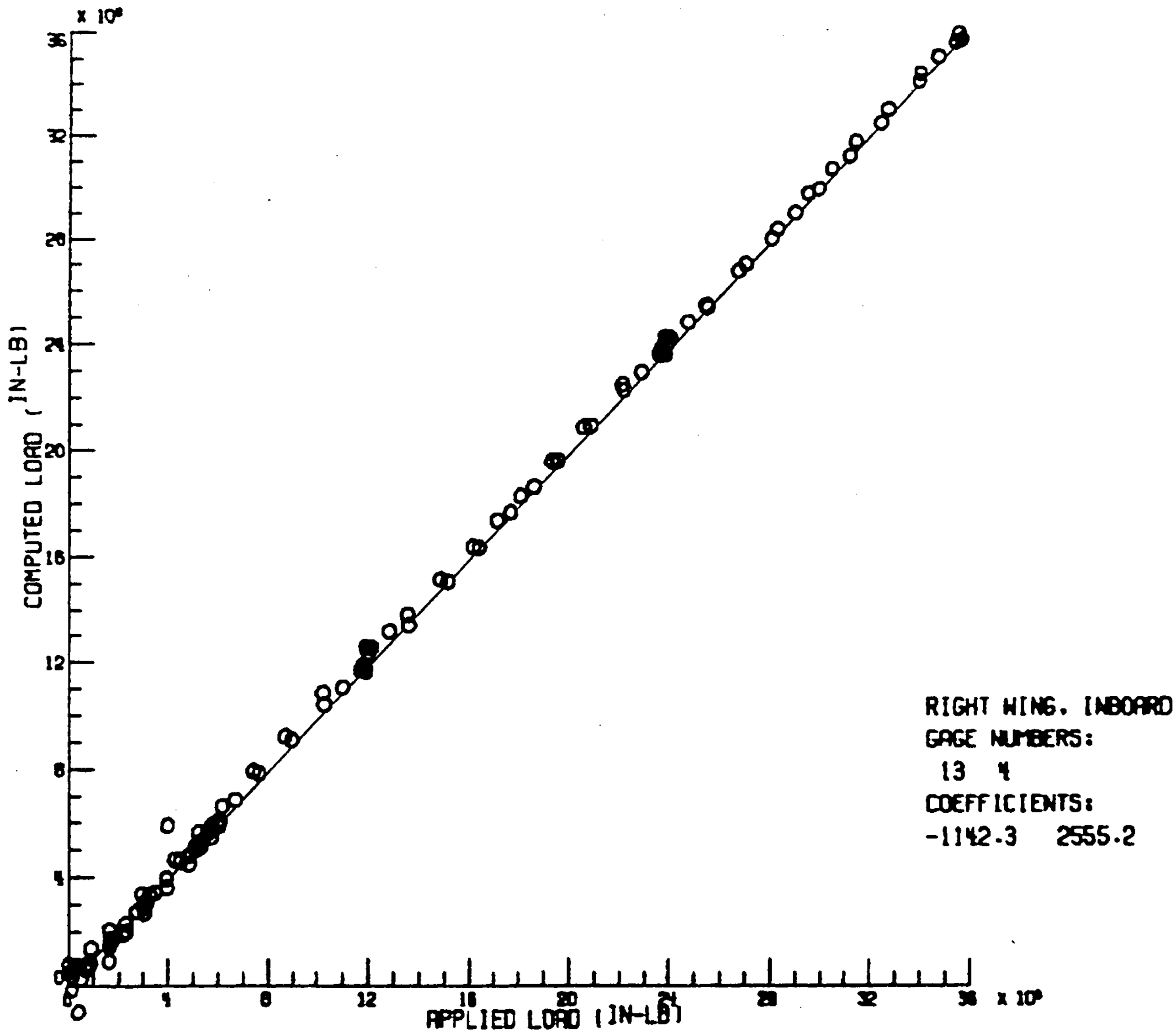
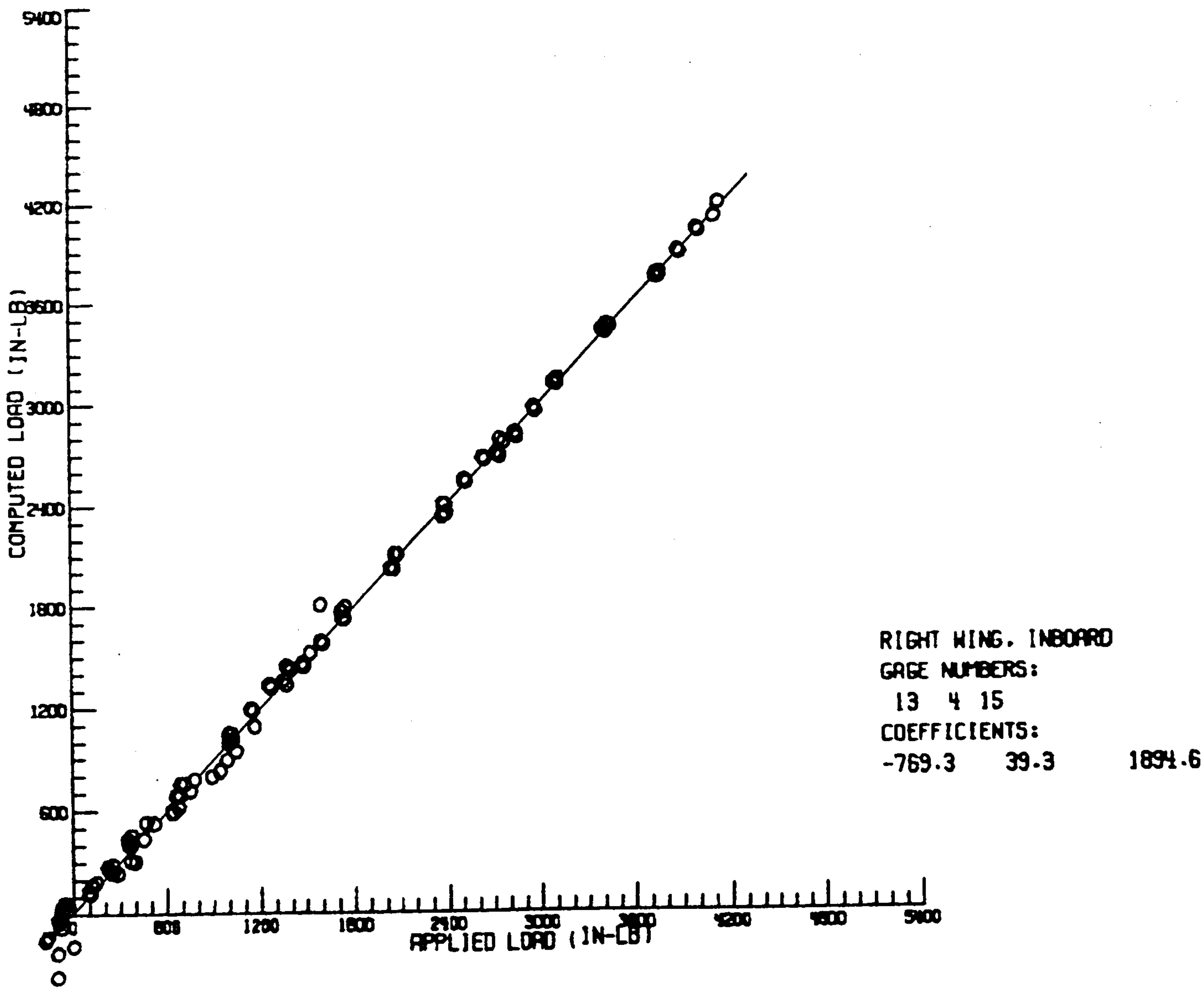


Figure 11.- Correlation of computed shear loads with applied calibration shear loads for the right wing inboard station.



BENDING MOMENT, COMBINED LOADINGS

Figure 12.- Correlation of computed bending moment loads with applied calibration bending moment loads for the right wing inboard station.



TORQUE, COMBINED LOADINGS

Figure 13.- Correlation of computed torque loads with applied calibration torque loads for the right wing inboard station.

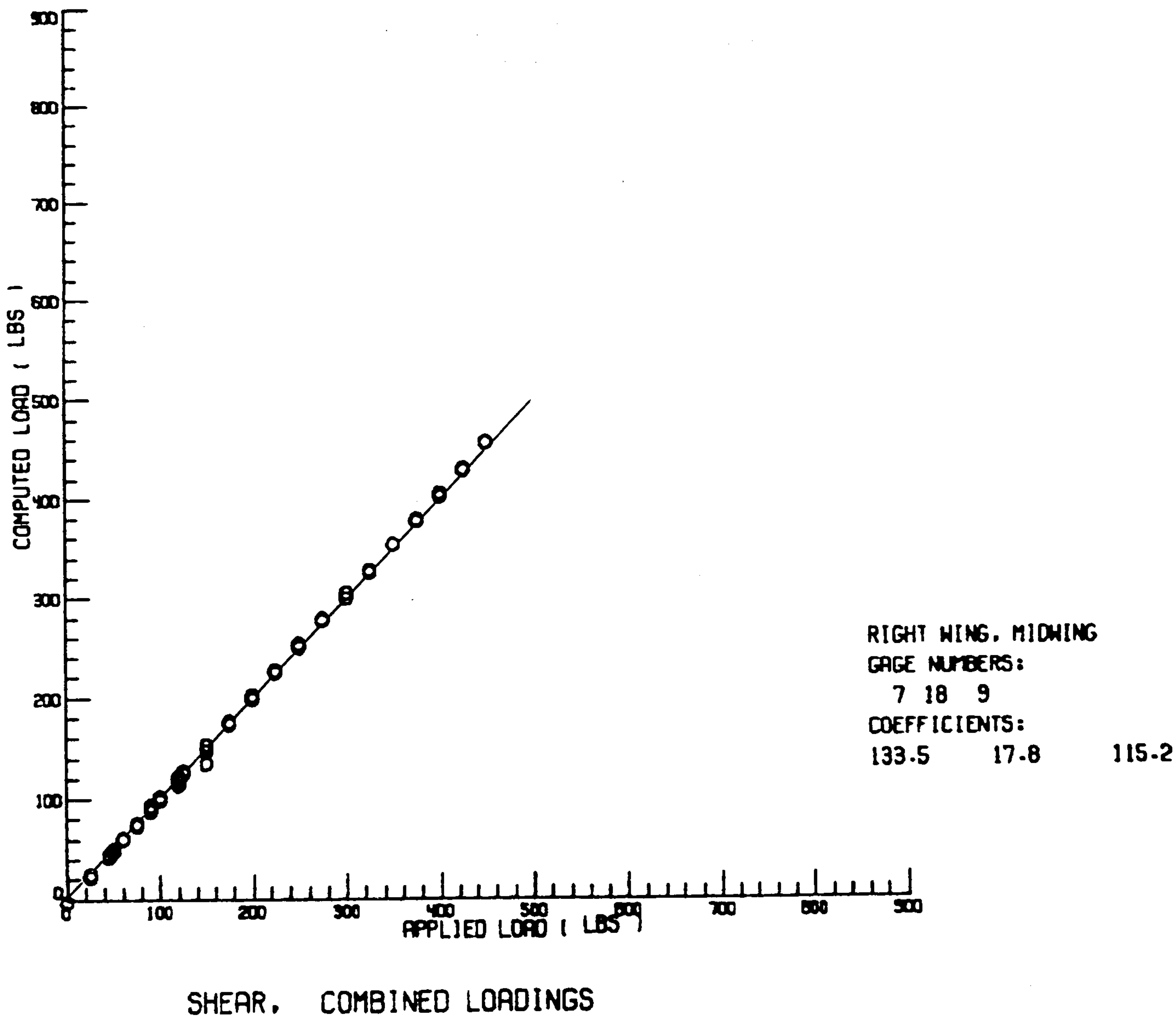
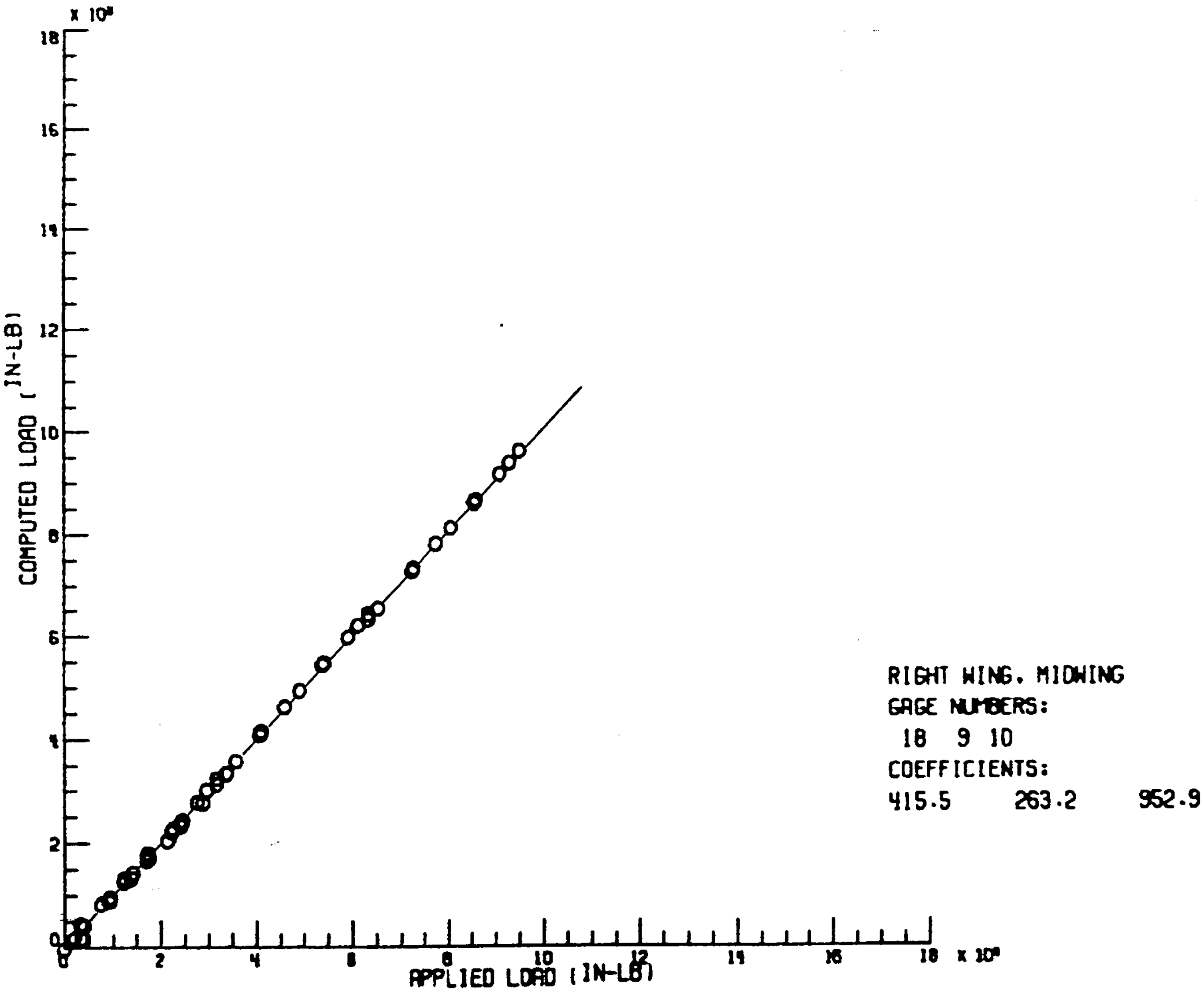


Figure 14.- Correlation of computed shear loads with applied shear loads for the right wing midwing station.



BENDING MOMENT, COMBINED LOADINGS

Figure 15.- Correlation of computed bending moment loads with applied bending moment load for the right wing midwing station.

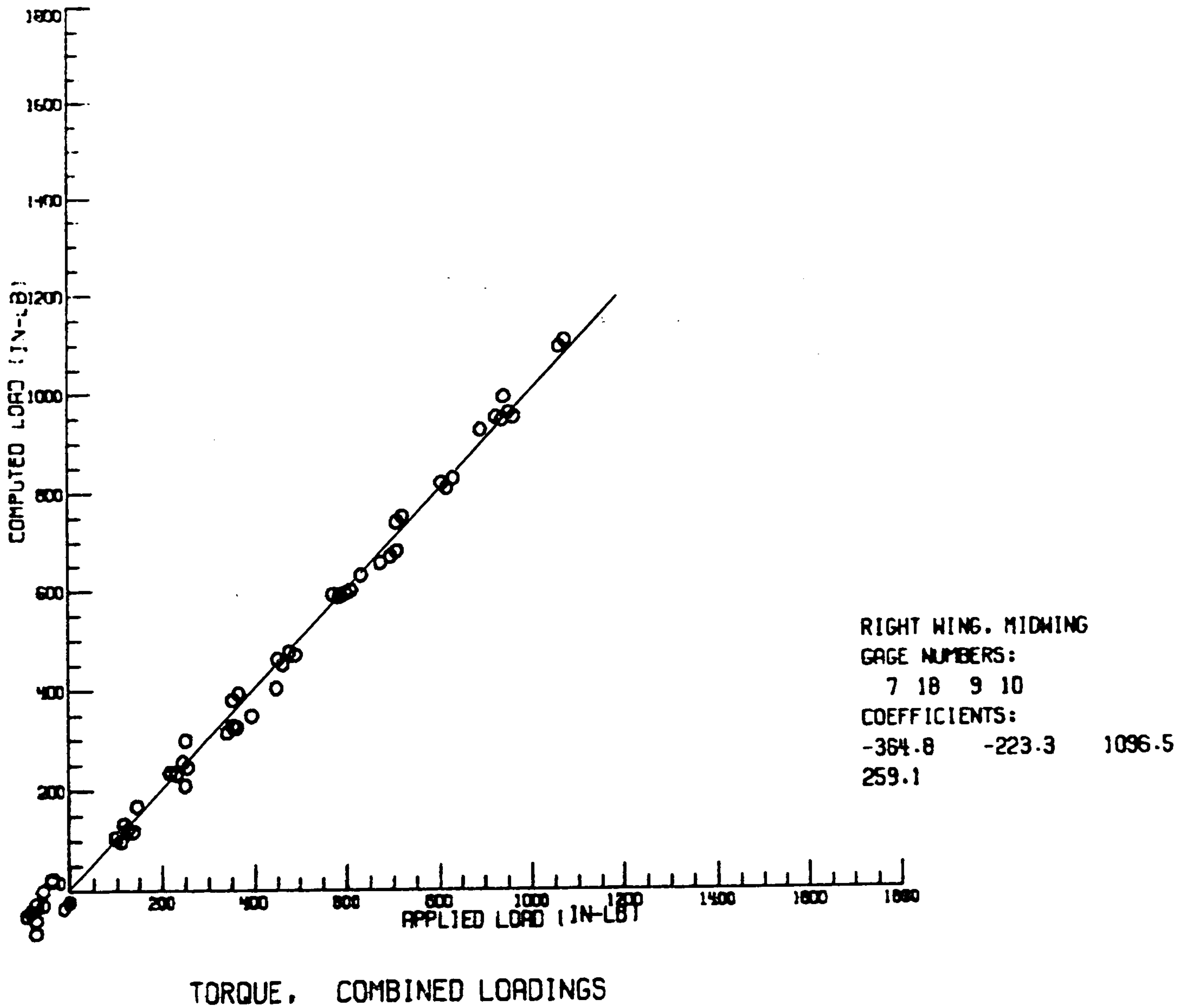


Figure 16.- Correlation of computed torque load with applied torque load for the right wing midwing station.

1. Report No. NASA TM-81889	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle LOADS CALIBRATIONS OF STRAIN GAGE BRIDGES ON THE DAST PROJECT AEROELASTIC RESEARCH WING (ARW-1)		5. Report Date October 1980
		6. Performing Organization Code
7. Author(s) Clinton V. Eckstrom		8. Performing Organization Report No.
9. Performing Organization Name and Address NASA Langley Research Center Hampton, VA 23665		10. Work Unit No. 505-33-53-02
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546		13. Type of Report and Period Covered Technical Memorandum
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This paper presents details of and results from the procedure used to calibrate strain gage bridges for measurement of wing structural loads, i.e., shear (V), bending moment (M), and torque (T), for the DAST project ARW-1 wing which has an aspect ratio of 6.8, a quarter-chord line sweepback angle of 42.24^{o}, and a taper ratio of 0.36. Results are in the form of loads equations and comparison of computed loads vs. actual loads for two simulated flight loading conditions.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Wing loads calibration Wing loads tests Strain gage bridges	Unclassified - Unlimited Subject Category 05

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	49	A03

* For sale by the National Technical Information Service, Springfield, Virginia 22161